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U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
150 Causeway Street
Boston 14, Mass.

NEDGW

31 July 1957

SUBJECT: Beach Erosion Control Report on Cooperative
Study of the Shore Between Pemberton Point
and Cape Cod Canal, Massachusetts.

TO: Chief of Engineers, Department of the Army,
Washington, D. C.

SYLLABUS

This study made in cooperation with the Commonwealth of Massachusetts includes all of the exposed coast between Pemberton Point, the most northerly point of the town of Hull, and the easterly entrance to Cape Cod Canal. The purpose of the study is to determine in general the best methods of shore protection, prevention of further erosion and improvement of beaches and specifically to develop plans for protection of Crescent Beach, The Glades, North Scituate Beach, Brant Rock and Plymouth Town Beach.

The Division Engineer recommends that protective measures which may be undertaken by local interests based on their own determination of economic justification be accomplished generally as follows:

- a. Crescent Beach. Widening about 2,000 feet of beach to a 125-foot width by direct placement of suitable sand fill and extending the existing stone revetment about 230 feet eastward.
- b. The Glades. Extending the stone breakwater about 350 feet northward or widening the beach in the same section to a width of 125 feet by direct placement of suitable sand fill.
- c. North Scituate Beach. Widening about 2500 feet of beach to a 125-foot width by direct placement of suitable sand fill.

The Division Engineer further recommends that the United States adopt projects authorizing Federal participation by the contribution of Federal funds in an amount equal to one-third the first costs of construction of the following projects.

- a. Brant Rock. Widening approximately 2,700 feet of public beach to a 125-foot width by direct placement of suitable sand fill and raising the inshore end of the Brant Rock jetty.

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- a. Brant Rock. Widening approximately 2,700 feet of public beach to a 125-foot width by direct placement of suitable sand fill and raising the inshore end of the Brant Rock jetty.

b. Plymouth Town Beach. Widening approximately 1300 feet of public beach to a 125-foot width, by direct placement of suitable sand fill and construction of two stone groins each about 300 feet long.

The estimated amounts of Federal participation in the first costs of the projects in accordance with the foregoing recommendations are \$49,300 for Brant and \$31,700 for Plymouth Town Beach.

b. Plymouth Town Beach. Widening approximately 1300 feet of public beach to a 125-foot width, by direct placement of suitable sand fill and construction of two stone groins each about 300 feet long.

The estimated amounts of Federal participation in the first costs of the projects in accordance with the foregoing recommendations are \$49,300 for Brant Rock and \$31,700 for Plymouth Town Beach.

Beach Erosion Control Report on Cooperative Study of the Shore
Between Pemberton Point and Cape Cod Canal, Massachusetts

I - GENERAL

1. Authority. - The study was made by the Corps of Engineers, United States Army, in cooperation with the Commonwealth of Massachusetts (acting through the Department of Public Works, Division of Waterways), under authority of Section 2 of the River and Harbor Act approved July 3, 1930, as amended and supplemented. Formal application for the cooperative study dated June 13, 1950 was approved by the Chief of Engineers on July 20, 1950. The initial study area included only the shore between Pemberton Point and Gurnet Point, Massachusetts. At the request of the Commonwealth by letter dated October 31, 1956 and approval by the Chief of Engineers on December 3, 1956 the study area was extended to include the shore between Plymouth (Long) Beach and the northerly entrance to the Cape Cod Canal.

2. Purpose. - The purpose of the study, as stated in the application (and amendments thereto) is to determine in general the best methods of shore protection, prevention of further erosion and improvement of beaches and specifically to develop plans for protection of Crescent Beach, the Glades, North Scituate Beach, Brant Rock and Plymouth Town Beach.

3. Prior Reports. - Two prior unprinted reports pertaining to shore processes in portions of the study area have been made.

a. A report was prepared by the District Engineer, Boston District, Corps of Engineers, dated December 18, 1939, subject, Study of Beach Erosion at North River, Massachusetts. The study concluded that North River maintains a stabilized channel thereby making the construction of jetties to assist in the maintenance of a channel unnecessary and that channel improvement without construction of jetties would have no effect upon the adjacent coast.

b. Beach Erosion Control Report on Cooperative Study of Metropolitan District Commission Beaches, Boston, Massachusetts: Part D - Nantasket Beach. Submitted to Congress on January 23, 1951. The Chief of Engineers recommended that the cooperating agency continue maintaining the beach in a suitable condition for recreational use, expanding its maintenance methods as necessary to bury and cover the stone deposits more completely or to remove the stones and replace them with equal volumes of sand.

4. Location. - The study area is located on the Atlantic coast in Massachusetts, covering all the exposed coast between Boston and Cape Cod Canal, not including protected harbor shore. The area is about 50 miles in length including the entire easterly shore of the towns of Hull, Cohasset, Scituate, Marshfield, Duxbury, Plymouth and Bourne, and the northerly tip of Sandwich. These towns cover all of the shore of Plymouth and Norfolk Counties and the northerly tip of Barnstable County. The center of the study area is about 40 miles southeast of Boston and 45 miles

east of Providence, Rhode Island. The area is shown on United States Coast and Geodetic Survey charts numbered 1207, 1208, 244, 245, 246 and 251; on United States Army Map Service Quadrangles of Hull, Nantasket, Cohasset, Scituate, Duxbury, Plymouth, Manomet and Sagamore, Massachusetts; and, on plates accompanying this report.

5. Population. - According to the 1950 census the Commonwealth of Massachusetts had a population of 4,690,514 which was an increase of 8.7 percent over that of 1940. The study area includes parts of the counties of Norfolk, Plymouth and Barnstable which had populations of 392,308, 189,468 and 48,805, respectively, in 1950. The study area included all or part of the shore of nine towns with a total population of 43,744, 1950 census. The distribution of the population according to towns, the percent increase between 1940 and 1950, and the lengths of shore within the study area are shown in Table 1.

Table 1. Population of Coastal Towns

<u>Town</u>	<u>Population (1950)</u>	<u>Percent Increase over 1940</u>	<u>Approximate Length of Shore Line in Study Area in Miles</u>
Hull	3,379	56	7.5
Cohasset	3,731	20	2.5
Scituate	5,993	45	10
Marshfield	3,267	35	4.5
Duxbury	3,167	34	4.5
Kingston	3,461	24	1.5
Plymouth	13,608	4	18
Bourne	4,720	42	1.5
Sandwich	2,418	78	1.5
Total	43,744	26	50*

*Omits shore of Kingston which is in Plymouth Harbor and therefore is not a part of the study area, but whose population uses the beaches in the study area.

The populations given are those of 1950 of residents who live in the towns throughout the year. Most of the shore towns are growing rapidly. Estimates by town officials indicate that the town of Hull now has a permanent population of about 6,000 and a summer population of about 35,000; the town of Scituate has a permanent population of about 10,000

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and a summer population of about 25,000; and the town of Plymouth has a permanent population of about 14,000 and a summer population of 60,000 to 70,000. In addition to summer residents, the use of the town is increased by house guests of the residents and visitors to the public beaches. The shore from Hull southward through Marshfield, inclusive, is more highly developed than the remainder of the area, and the greater part of the population of the towns is grouped near the shore with the inland parts less densely populated. The towns of Bourne and Sandwich have additional shore on Buzzards Bay or south of the study area, but are considered to contribute to beach use in the study area. Probably equally important to beach use is the population of nearby inland towns and nearby towns where beach overcrowding is severe. A list of larger towns of this classification is given in Table 2.

Table 2. Population of Nearby Cities and Towns

<u>Town</u>	<u>Population (1950)</u>	<u>Percent Increase 1940-1950</u>	<u>Approximate Distance from Study Area in Miles*</u>
Boston	801,444	4	18
Cambridge	120,740	9	19
Milton	22,395	20	13
Brockline	57,589	16	18
Quincy	83,835	11	11
Weymouth	32,690	14	9
Braintree	23,161	41	9
Dedham	18,487	19	18
Brockton	62,860	1	18
Taunton	40,109	7	21
Newton	81,994	17	21
Wellesley	20,549	36	27
Framingham	28,096	21	33
Needham	16,313	31	22
Natick	19,838	43	30
Norwood	16,636	8	19
Total	1,446,736	8.7	

*From center of town to nearest shore in study area.

6. Several forms of transportation are available to the beach area. United States highways number 1A and 6, State of Massachusetts highways 3, 3A, 106, 123 and 139, and many local roads run to or along the shore, various public bus lines serve the area and a branch of the New York, New Haven and Hartford Railroad runs from Boston to Greenbush in Scituate. During the summer months, a public ferry runs from Boston to Nantasket Beach in Hull and the Metropolitan Transit Authority, provides bus service to Nantasket.

7. Description. - The study area is a shore line of submergence which varies widely in composition. Hull, northwest of Atlantic Hill, consists of a series of tombolos in which five glacial till islands are tied by sand accretion. From Atlantic Hill, through Cohasset to North Scituate, the shore is largely bedrock with small pocket beaches. The northerly part of the shore of North Scituate has narrow sand beaches fronting sea walls, while along the southerly part of North Scituate the shore consists of a shingle barrier which formed during the severe northeast storm of November 1898 and protects a backshore of low land, marsh and a fresh water pond. The beaches are narrow and generally coarse along the four glacial till cliffs south of Scituate Harbor. Humarock Beach, comprising the remainder of the shore in Scituate, is a desirable, relatively wide beach area. Between Marshfield town line and Green Harbor the beach is wide along the northerly mile then becomes narrow and stony except at Brant Rock where groins have been constructed and sand fill added. South of Green Harbor there is a wide sandy beach adjacent to the south jetty followed by relatively narrow beach and high backshore through the residential portion of Duxbury. Southerly therefrom the area consists of a tombolo to Gurnet Point and Saquish Head with wide sandy beaches. This tombolo forms the northerly shelter for Plymouth Harbor. Plymouth (Long) Beach, a spit about three miles in length, forms the southerly arm sheltering Plymouth Harbor. Warren Cove formed by Plymouth Long Beach and Rocky Point and containing Plymouth Town Beach, has a low marshy backshore. Rocky Point is a high glacial till bluff. Thereon to a point about two miles north of the canal, the shore is high glacial till or sand bluffs fronted by medium to narrow beaches. The southerly two miles of shore, comprising Scusset Beach, is relatively wide with low backshore.

8. The area between Pemberton Point and Plymouth Beach, except on the Duxbury Beach tombolo, is highly developed and is protected almost throughout by sea walls or revetment. The remainder of the area is sparsely developed and shore protection structures consist principally of groin systems. Further description and information relative to protective structures may be found in Appendices A and F.

9. The shore is principally privately owned, however, publicly owned shores of the Federal government, the Commonwealth and various towns are scattered throughout. In addition there are town-owned beaches restricted to town residents or beach association members only. A listing of these shores follow in Table 3:

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6. Several forms of transportation are available to the beach area. United States highways number 14 and 6, State of Massachusetts highways 3, 3A, 106, 123 and 139, and many local roads run to or along the shore, various public bus lines serve the area and a branch of the New York, New Haven and Hartford Railroad runs from Boston to Greenbush in Scituate. During the summer months, a public ferry runs from Boston to Nantasket Beach in Hull and the Metropolitan Transit Authority, provides bus service to Nantasket.

7. Description. - The study area is a shore line of submergence which varies widely in composition. Hull, northwest of Atlantic Hill, consists of a series of tombolos in which five glacial till islands are tied by sand accretion. From Atlantic Hill, through Cohasset to North Scituate, the shore is largely bedrock with small pocket beaches. The northerly part of the shore of North Scituate has narrow sand beaches fronting sea walls, while along the southerly part of North Scituate the shore consists of a shingle barrier which formed during the severe north-east storm of November 1898 and protects a backshore of low land, marsh and a fresh water pond. The beaches are narrow and generally coarse along the four glacial till cliffs south of Scituate Harbor. Humarock Beach, comprising the remainder of the shore in Scituate, is a desirable, relatively wide beach area. Between Marshfield town line and Green Harbor the beach is wide along the northerly mile then becomes narrow and stony except at Brant Rock where groins have been constructed and sand fill added. South of Green Harbor there is a wide sandy beach adjacent to the south jetty followed by relatively narrow beach and high backshore through the residential portion of Duxbury. Southerly therefrom the area consists of a tombolo to Gurnet Point and Saquish Head with wide sandy beaches. This tombolo forms the northerly shelter for Plymouth Harbor. Plymouth (Long) Beach, a spit about three miles in length, forms the southerly arm sheltering Plymouth Harbor. Warren Cove formed by Plymouth Long Beach and Rocky Point and containing Plymouth Town Beach, has a low marshy backshore. Rocky Point is a high glacial till bluff. Thereon to a point about two miles north of the canal, the shore is high glacial till or sand bluffs fronted by medium to narrow beaches. The southerly two miles of shore, comprising Scusset Beach, is relatively wide with low backshore.

8. The area between Pemberton Point and Plymouth Beach, except on the Duxbury Beach tombolo, is highly developed and is protected almost throughout by sea walls or revetment. The remainder of the area is sparsely developed and shore protection structures consist principally of groin systems. Further description and information relative to protective structures may be found in Appendices A and F.

9. The shore is principally privately owned, however, publicly owned shores of the Federal government, the Commonwealth and various towns are scattered throughout. In addition there are town-owned beaches restricted to town residents or beach association members only. A listing of these shores follow in Table 3:

Table 3. Principal Publicly owned Shores

<u>Town</u>	<u>Area</u>	<u>Owner</u>	<u>Length of Shore in feet</u>	<u>Use</u>
Hull	Nantasket Beach	Met. Dist. Comm. (State)	5,700	Public bathing beach (1.2.)
Cohasset	North End	Town	600	Bathing beach
	Town Beach	Town	1,000	Resident only bathing beach (1.2.)
Scituate	Egypt Beach	Town	710	Public bathing beach
	Sand Hills	Town	550	Bathing beach
	Sand Hills	Town	1,260	Bathing beach
	Cedar Point	Town	400	Historical lighthouse
	Peggotty Beach	Town	750	Bathing beach
	Fourth Cliff	Federal (Air Force)	1,300	Military reservation
	Humarock Beach	Town	1,300	Bathing beach
Marshfield	Brant Rock Beach	Town	2,700	Public bathing beach (2.)
	Green Harbor	Town	3,000	Resident bathing beach (1.2.)
Duxbury	Duxbury (3)	Duxbury Beach Association	3,500	Members only on Sat., Sun., & holidays; public remainder of time.
Plymouth	Gurnet Point	Federal (Coast Guard)	1,000	Lighthouse (1.2.)
	Town Beach	Town	1,300	Public bathing beach (1.2.)
Sandwich	Scusset Beach	Federal (Corps of Engrs.) leased to State	2,100	Public bathing beach & recreation area

(1.) Bathhouse available

(2.) Parking facilities available

(3.) The administration of this beach is delegated to the Duxbury Beach Association.

The resident only and membership beaches are generally controlled by requiring a car tag to park or a membership card to use the bathhouse. In other words, the general public may use the beaches by dressing and by parking their cars away from the vicinity of the beach. In addition to the publicly owned shores, some towns maintain beaches for public use although the backshore may be privately owned. The towns of Scituate and Marshfield maintain that beach area seaward of the sea wall is for public use and assume maintainance of these areas. The Town of Scituate collects no taxes for area seaward of the sea walls. A listing of publicly maintained and used private shores follows:

Table 4. Publicly Maintained Areas.

<u>Town</u>	<u>Area</u>	<u>Length of Shore</u>	<u>Facilities furnished</u>
Hull	North Nantasket Beach	11,000 feet	Life guard, trash disposal, water fountains
	Gun Rock Beach	1,000 feet	Trash disposal, cleaning
Scituate	All south of Association beach	7 miles	Cleaning only except at town-owned beaches
Marshfield	All	4.5 miles	Cleaning only except at town-owned beaches

10. Statement of the Problem. - The problem is basically one of general erosion due principally, as in most areas, to the advanced development of the shore and the erection of protective structures which have eliminated sources for the supply of littoral material to the shore which formerly provided equilibrium under natural shore processes. The study area north of Plymouth is largely protected by sea walls generally with narrow beaches fronting them. These walls are often damaged during storms. During the summer months there is insufficient beach area to accommodate bathers. Therefore the problem in this area is associated with prevention of damage to existing structures as well as the restoration of eroded beaches. Local interests desire general treatment of the problems except at Crescent Beach in Hull, the Glades and North Scituate Beach in Scituate, Brant Rock in Marshfield, and Town Beach in Plymouth, for which detailed plans of improvement are requested. At Crescent Beach the shore has been severely eroded, leaving a beach of gravel and cobble, and during a storm in March 1956 approximately 175 feet of sea wall was undermined and tipped over. The problem at the Glades has essentially been resolved since initiation of the study by construction of an offshore breakwater (structure 29, see Appendix F) by the Commonwealth. At the north end of North Scituate Beach, the portion administered by the Scituate Beach Association, the beach has become quite narrow and very little area remains above high water. Local interests desire to restore the beach to provide adequate area for resident bathing. At the south end of North Scituate Beach the shingle barrier protecting the low backshore from ocean flooding during extreme tides is eroding along the face and at points along the crest. Protection of this barrier is desired as its loss would allow flooding of a large portion of the town of Scituate during storms. The public beach at Brant Rock has been subject to erosion over a

18. Because of extensive protective works there are very few sources of material between Pemberton Point and Duxbury. In this area the high Allerton Hill in Hull, composed of glacial till with high sand content, and the low unprotected sand dunes along northerly Nantasket Beach supply some material to the southerly part of Nantasket Beach. From Atlantic Hill southward to Duxbury the bedrock cliffs and protective works limit sources to beach areas or localized areas of erosion behind or above sea walls and revetments. Duxbury Beach provides a source of sand to littoral drift. From Plymouth center to south of Rocky Point the source of material is limited to beach areas. South from Rocky Point high sand bluffs or bluffs of glacial till of high sand content, are eroding and supplying sand to littoral drift. This bluff erosion is especially active in the area between Lookout Point and Scusset Beach. In general, sources for artificial fill material would be inland deposits.

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21. Prior Corrective Action and Existing Structures. - This phase of the study is presented in detail in Appendix F. Each structure is located, numbered and described in the Appendix and on Plates 2 - 9. In general sea walls, revetments and groin systems have been placed throughout the length of the shore between Pemberton Point and the center of Duxbury, Brant Rock being the only location in this portion of the study area where artificial sand fill has been placed on the shore. South of Plymouth Harbor to Cape Cod Canal there is only about 2,600 feet of concrete sea wall (67) which extends from the north end of Plymouth Town Beach to a point about 1,300 southward of the south end of the beach. Revetments are located along Plymouth (Long) Beach, (66) south from the sea wall (70, 71), along north side of Manomet Point (80), and between Manomet Point and Stage Point (83). Various groin systems are located

18. Because of extensive protective works there are very few sources of material between Pemberton Point and Duxbury. In this area the high Allerton Hill in Hull, composed of glacial till with high sand content, and the low unprotected sand dunes along northerly Nantasket Beach supply some material to the southerly part of Nantasket Beach. From Atlantic Hill southward to Duxbury the bedrock cliffs and protective works limit sources to beach areas or localized areas of erosion behind or above sea walls and revetments. Duxbury Beach provides a source of sand to littoral drift. From Plymouth center to south of Rocky Point the source of material is limited to beach areas. South from Rocky Point high sand bluffs or bluffs of glacial till of high sand content, are eroding and supplying sand to littoral drift. This bluff erosion is especially active in the area between Lookout Point and Scusset Beach. In general, sources for artificial fill material would be inland deposits.

19. Littoral Forces. a. Waves. - No wave observations have been made along the coast from Pemberton Point to the Cape Cod Canal entrance. Wave characteristics used in this report were derived by hindcast methods for a station in deep water off Nauset Beach, Cape Cod, about 70 miles east-southeast of the center of the study area. Table C-2 and the wave rose on Plate 1 indicate that the predominant direction of wave approach is from the east and east-northeast directions. The study area is exposed to ocean waves generated over long fetches from directions of north to east. From the directions of north to northwest the fetch is limited by Boston Harbor, and Cape Cod limits the fetch for directions of east to south-southeast.

b. Winds. - United States Weather Bureau wind records for Boston, Massachusetts, the weather station located nearest to the study area, for the 7 year period October 1949 through September 1956 have been used. These data consist of hourly observations of wind speed and direction, based on sixteen points of the compass. From the wind rose, shown on Plate 1, it may be concluded that prevailing winds are from westerly directions, or offshore with respect to the study area, and that predominant onshore winds are from east to northeast. More detailed data may be found in Appendix C.

c. Storms. - Two types of storms cause the principal damage to New England coastal areas, tropical cyclones or hurricane intensity and northeast storms. Greatest damage of record to the study area was caused by the northeast storms of April 20-22, 1940 and November 28-30, 1945. These storms maintained gale velocity for 31 and 53 hours with maximum velocity of the 1945 storm reaching 68 miles per hour. Such storms have increased water elevations in Boston Harbor to 13.8 feet above mean low water and action of waves upon these extreme heights cause much damage to shore property. Storms are discussed in detail in Appendix C and a diagram showing distribution of winds over 32 miles per hour circumscribe the wind rose shown on Plate 1.

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22. Profiles. - Field survey work was limited in this study, and profiles were taken only at five locations. Detailed data on beach slopes at profiles are included in Appendix A. The profiles were located as follows (see Plates 2-9): 4 profiles from the sea wall to mean low water at Crescent Beach, 3 profiles at North Scituate Bathing Beach, extending from the sea wall to about 13 feet below mean low water; 1 profile along the top of the bar and three cross sections at Mann Hill Beach in North Scituate; 6 profiles at Brant Rock extending from the sea wall to mean low water; and, 4 profiles at Plymouth Town Beach, extending from the sea wall to 18 feet below mean low water. The profiles indicated foreshore slopes as follows: Crescent Beach 1 on 5 to 1 on 10, North Scituate Bathing Beach from 1 on 12 to 1 on 25, Mann Hill Beach 1 on 8 to 1 on 11, Brant Rock 1 on 6 to 1 on 16, and Plymouth Town Beach about 1 on 20. The small amount of comparative data that was available is plotted with the 1956 profiles on Plate 18. These comparative profiles were not considered indicative of the normal rate of erosion, nor of the carrying capacity of the littoral current, since protective works and narrow coarse beaches had prevented further retreat of the banks thereby reducing the amount of material available for transport from the site. Assumed profiles were therefore established to derive estimated sand replenishment values for restored beaches. In a personal communication Dr. John M. Zeigler, Woods Hole Oceanographic Institution, reported on a series of profiles at two locations about 100 feet apart on Duxbury Beach, located on the seaward side of the tombolo opposite the east end of the Powder Point Bridge. Profiles extended generally from the berm approximately to the low water line. The profiles appear to change in a cyclic pattern of irregular time intervals. At the northerly location (Duxbury A) the foreshore eroded from September to the latter part of October 1953, partially recovered until the first week in February 1954, eroded again until the middle of April, then recovered again until July 1, 1954. A similar pattern of change occurred from August 11, 1954 to May 6, 1955. The southerly profile (Duxbury B) followed generally the same pattern as Duxbury A for the period August 11, 1954 to May 6, 1955.

III. ANALYSIS OF THE PROBLEM

23. General. - Wave action is the principal cause of damage in the study area, both for loss of beach material and damage to existing structures. The conditions of shore orientation, rock exposure and bluff materials differ materially in the several sections of the study area, leading to differences in protective requirements and suitability of methods of protection. Briefly summarized, the characteristics of the several sections are as follows:

a. Pemberton Point to Point Allerton. - This section comprises two former islands and connecting tombolo. The area is low and sandy except at Point Allerton, a part of one of the tied islands. The shore line has not changed significantly in recent years due to the high degree of protective works consisting of sea walls, revetments, bulkheads and groins. The protective works are generally in fair to good condition except for the concrete sea wall along Nantasket Avenue which is crumbling and in generally bad condition. The section is in effect one headland without any material supply, but with littoral forces adequate to move beach material rapidly westward. Maintenance of existing walls and revetments appears to be the most suitable method of protection.

b. Point Allerton to Scituate Harbor. - From Point Allerton to Scituate Harbor, the shore consists of relatively short pocket beaches between resistant headlands. There is practically no supply of material to the beaches at present. Littoral transport out of the pockets appears to be very small. Although artificially placed fills would be subject to onshore-offshore movement, losses would probably be low, except that where waves approach at an angle such as at Crescent Beach, groins would be needed to retain the fill, at least at the downdrift headland. Concrete sea walls as constructed result in loss of protective beach, and waves break over the walls causing damages to roads and buildings. Prevention of such damages could be prevented by placement and periodic restoration of a protective beach, or by construction of heavy revetments of such height as to absorb the wave energy without being overtopped.

c. Scituate Harbor to Gurnet Point. - From Scituate Harbor to Gurnet Point, the conditions are similar to those in the preceding section except that the lengths of the pocket beaches are much greater. Only two relatively long pocket beaches, First Cliff to Brant Rock and Brant Rock to Gurnet Point, are involved. The North River mouth breaks the continuity of the former and much littoral material is stored in its bars. The First Cliff - Third Cliff section could be compartmented by a jetty at its south end and the protective beach could be widened artificially. The rate of loss therefrom would probably be low. The Fourth Cliff - Brant Rock section could similarly be improved by artificial placement of sand possibly with a short jetty at Fourth Cliff to prevent loss northward into the mouth of North River with probable deposition on the spit extending southwestward from the Fourth Cliff. Since the Scituate and Marshfield shores will eventually require periodic nourishment for their stabilization,

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it would be desirable for local interests to acquire suitable sand deposits for that purpose.

d. Warren Cove. - Warren Cove is a short reach extending from a headland and ending in a spit. Littoral forces tending to produce drift toward the end of the spit would no doubt move considerable material if the supply were increased. Beach widening by artificial placement with groins to reduce losses appears to be the most suitable method of improvement for the beach. Any plan for nourishing Long Beach would necessitate a longer jetty at its north end to prevent losses into the harbor channels.

e. Rocky Point to Manomet Point. - From Rocky Point to Manomet Point the orientation is such that material eroded from the bluffs probably remains within the reach. If a wider protective or recreational beach is required, it would probably necessitate structures to extend the points seaward as elongated headlands to retain the widened beach.

f. Manomet Point to Cape Cod Canal. - From Manomet Point to Cape Cod Canal, eroding sandy bluffs probably supply considerable material to the beaches and littoral forces produce a predominant southward littoral drift. Groins appear to be effective in widening the beaches. Where no development necessitates stabilization of the bluffs, they should be permitted to recede to provide material to the beaches. With groins to retain the material, the beaches could be expected to build up and eventually protect the toe of the bluffs.

24. Design Criteria. - Proposed protective measures are designed to provide protection against ordinary conditions of comparatively frequent occurrence (at least once each year). They are not intended to provide complete protection to waterfront structures in event of a hurricane or exceptional storms of infrequent occurrence, although even under these conditions some protection will be afforded. Specific design criteria used for protective works are as follows:

a. Design Tide. - The design tide is the maximum elevation which occurs at least once each year. Tide records at Boston indicate that stages in excess of 3 feet above the plane of mean high water occur about once each year.

b. Groins. - The horizontal shore section should ordinarily have a top elevation not lower than the general height of berms of existing beaches and a length equal to the berm width of the anticipated beach. In the study area, the top elevation should be approximately 5 feet above the plane of mean high water. Barrier groins which are intended to completely block passage of littoral drift or to reduce it considerably should be higher than the anticipated beach berm. Also in the case of stone groins it is desirable to have the top elevation about 1 foot higher because of the spaces between cover stones. The intermediate sloped section should not be steeper than the slope of the existing foreshore, and should approximately equal the anticipated beach slope. The top elevation of the outer section should not be lower than 1 foot above the plane of mean low water. For stone construction, the minimum height of groins should be 3 feet.

Groins should be sand tight and firmly anchored at their shore ends to prevent flanking. Groin lengths are generally determined by the shape of the fillet and required width at the updrift end of the space between groins. Stone sizes and side slopes for groins are computed using the Iribarren method as described in Technical Report No. 4 of the Beach Erosion Board entitled "Shore Protection Planning and Design." The design wave used is the maximum wave that can approach, without breaking, in the depth of water at the groin if the fetch is not a limiting factor. Throughout the study area, such maximum waves can be generated with the available fetch. Blankets of spalls or crushed stone are used under stone groins or jetties to minimize settlement due to scour.

c. Sand Fills. - Berm elevations of proposed fills are based on those of existing beach berms. The minimum width of fills is based on widths found to afford protection in the area. Computed volumes of fills are based on slopes similar to existing slopes but fills can be placed initially to a steeper slope and permitted to take a natural slope under wave action. Based on these criteria berm elevations are approximately 5 feet above mean high water and beach widths above mean high water are approximately 125 feet with fill slopes of 1 on 20 to 1 on 30. Suitable sand for beach fills would have size and gradation characteristics similar to those of the sand components of the existing material on beaches. In cases where protective structures along the shore prevent natural erosion and the transport is less than the transport capacity of the littoral currents it is assumed that provision of a wide beach will increase the drift movement to a quantity more nearly equal to the normal carrying capacity. In this area the average annual recession is about 2 feet. The replenishment quantity is estimated to be about 3,000 cubic yards of suitable sand per year at each beach. For the purpose of detailed design of beach fills, the investigations of materials on the beaches and in proposed borrow areas given in this report must be supplemented when plans and specifications are being prepared.

IV. PLANS OF IMPROVEMENT

25. General. - The formal application (as amended) requested detailed investigation of five beaches in the study area, Crescent Beach in Hull, The Glades in Scituate, North Scituate Beach in Scituate, Brant Rock Beach in Marshfield and Plymouth Town Beach in Plymouth. Detailed plans of improvement have been prepared for these areas and for the more important intervening areas general suggestions as to type of improvement which may be used are discussed. This information follows in geographic order.

26. Nantasket Beach. (Plate 2) - Nantasket Beach is a beach about $3\frac{1}{2}$ miles long tying Allerton Hill and Atlantic Hill together. The problem at this beach concerns the recurrence of gravel on the foreshore making the beach less desirable from the standpoint of both comfort and appearance. Local interests also indicate that narrowing of the north end, as indicated by shore line change data, has occurred during the last few years. The

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b. Groins. - The horizontal shore section should ordinarily have a top elevation not lower than the general height of berms of existing beaches and a length equal to the berm width of the anticipated beach. In the study area, the top elevation should be approximately 5 feet above the plane of mean high water. Barrier groins which are intended to completely block passage of littoral drift or to reduce it considerably should be higher than the anticipated beach berm. Also in the case of stone groins it is desirable to have the top elevation about 1 foot higher because of the spaces between cover stones. The intermediate sloped section should not be steeper than the slope of the existing foreshore, and should approximately equal the anticipated beach slope. The top elevation of the outer section should not be lower than 1 foot above the plane of mean low water. For stone construction, the minimum height of groins should be 3 feet.

Groins should be sand tight and firmly anchored at their shore ends to prevent flanking. Groin lengths are generally determined by the shape of the fillet and required width at the updrift end of the space between groins. Stone sizes and side slopes for groins are computed using the Iribarren method as described in Technical Report No. 4 of the Beach Erosion Board entitled "Shore Protection Planning and Design." The design wave used is the maximum wave that can approach, without breaking, in the depth of water at the groin if the fetch is not a limiting factor. Throughout the study area, such maximum waves can be generated with the available fetch. Blankets of spalls or crushed stone are used under stone groins or jetties to minimize settlement due to scour.

c. Sand Fills. - Berm elevations of proposed fills are based on those of existing beach berms. The minimum width of fills is based on widths found to afford protection in the area. Computed volumes of fills are based on slopes similar to existing slopes but fills can be placed initially to a steeper slope and permitted to take a natural slope under wave action. Based on these criteria berm elevations are approximately 5 feet above mean high water and beach widths above mean high water are approximately 125 feet with fill slopes of 1 on 20 to 1 on 30. Suitable sand for beach fills would have size and gradation characteristics similar to those of the sand components of the existing material on beaches. In cases where protective structures along the shore prevent natural erosion and the transport is less than the transport capacity of the littoral currents it is assumed that provision of a wide beach will increase the drift movement to a quantity more nearly equal to the normal carrying capacity. In this area the average annual recession is about 2 feet. The replenishment quantity is estimated to be about 3,000 cubic yards of suitable sand per year at each beach. For the purpose of detailed design of beach fills, the investigations of materials on the beaches and in proposed borrow areas given in this report must be supplemented when plans and specifications are being prepared.

IV. PLANS OF IMPROVEMENT

25. General. - The formal application (as amended) requested detailed investigation of five beaches in the study area, Crescent Beach in Hull, The Glades in Scituate, North Scituate Beach in Scituate, Brant Rock Beach in Marshfield and Plymouth Town Beach in Plymouth. Detailed plans of improvement have been prepared for these areas and for the more important intervening areas general suggestions as to type of improvement which may be used are discussed. This information follows in geographic order.

26. Nantasket Beach. (Plate 2) - Nantasket Beach is a beach about $3\frac{1}{2}$ miles long tying Allerton Hill and Atlantic Hill together. The problem at this beach concerns the recurrence of gravel on the foreshore making the beach less desirable from the standpoint of both comfort and appearance. Local interests also indicate that narrowing of the north end, as indicated by shore line change data, has occurred during the last few years. The

it would be desirable for local interests to acquire suitable sand deposits for that purpose.

d. Warren Cove. - Warren Cove is a short reach extending from a headland and ending in a spit. Littoral forces tending to produce drift toward the end of the spit would no doubt move considerable material if the supply were increased. Beach widening by artificial placement with groins to reduce losses appears to be the most suitable method of improvement for the beach. Any plan for nourishing Long Beach would necessitate a longer jetty at its north end to prevent losses into the harbor channels.

e. Rocky Point to Manomet Point. - From Rocky Point to Manomet Point the orientation is such that material eroded from the bluffs probably remains within the reach. If a wider protective or recreational beach is required, it would probably necessitate structures to extend the points seaward as elongated headlands to retain the widened beach.

f. Manomet Point to Cape Cod Canal. - From Manomet Point to Cape Cod Canal, eroding sandy bluffs probably supply considerable material to the beaches and littoral forces produce a predominant southward littoral drift. Groins appear to be effective in widening the beaches. Where no development necessitates stabilization of the bluffs, they should be permitted to recede to provide material to the beaches. With groins to retain the material, the beaches could be expected to build up and eventually protect the toe of the bluffs.

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a. Design Tide. - The design tide is the maximum elevation which occurs at least once each year. Tide records at Boston indicate that stages in excess of 3 feet above the plane of mean high water occur about once each year.

b. Groins. - The horizontal shore section should ordinarily have a top elevation not lower than the general height of berms of existing beaches and a length equal to the berm width of the anticipated beach. In the study area, the top elevation should be approximately 5 feet above the plane of mean high water. Barrier groins which are intended to completely block passage of littoral drift or to reduce it considerably should be higher than the anticipated beach berm. Also in the case of stone groins it is desirable to have the top elevation about 1 foot higher because of the spaces between cover stones. The intermediate sloped section should not be steeper than the slope of the existing foreshore, and should approximately equal the anticipated beach slope. The top elevation of the outer section should not be lower than 1 foot above the plane of mean low water. For stone construction, the minimum height of groins should be 3 feet.

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c. Sand Fills. - Berm elevations of proposed fills are based on those of existing beach berms. The minimum width of fills is based on widths found to afford protection in the area. Computed volumes of fills are based on slopes similar to existing slopes but fills can be placed initially to a steeper slope and permitted to take a natural slope under wave action. Based on these criteria berm elevations are approximately 5 feet above mean high water and beach widths above mean high water are approximately 125 feet with fill slopes of 1 on 20 to 1 on 30. Suitable sand for beach fills would have size and gradation characteristics similar to those of the sand components of the existing material on beaches. In cases where protective structures along the shore prevent natural erosion and the transport is less than the transport capacity of the littoral currents it is assumed that provision of a wide beach will increase the drift movement to a quantity more nearly equal to the normal carrying capacity. In this area the average annual recession is about 2 feet. The replenishment quantity is estimated to be about 3,000 cubic yards of suitable sand per year at each beach. For the purpose of detailed design of beach fills, the investigations of materials on the beaches and in proposed borrow areas given in this report must be supplemented when plans and specifications are being prepared.

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- e. Plymouth Town Beach . - Beach widening,
55,000 cubic yards of sand fill;
construction two groins each 300
feet long. \$ 95,000

37. Estimate of Benefits. - Benefits have been evaluated for projects at Brant Rock and Plymouth Town Beach. Estimated benefits from prevention of damages are based on amounts actually spent in the past for replacement of protective structures and repair of storm damages. Land losses are not considered as retreat of the shore has been prevented by protective structures. Recreation benefits are computed assuming a benefit per visit equal to an average charge of \$0.25 for attending beaches with similar facilities. Estimates of benefits are presented in detail in Appendix I and are as follows:

ESTIMATES OF BENEFITS

<u>Location</u>	<u>Direct Damages Prevented</u>	<u>Recreational Benefits</u>	<u>Total Benefits</u>
Brant Rock	\$ 19,700	--	\$ 19,700
Plymouth	\$ 7,840	\$ 3,705	\$ 11,545

38. Interests. - There is no direct Federal interest in the projects for Brant Rock and Plymouth Town Beach since none of these shores are owned by the United States. Non-Federal public interest is defined as, (a) the benefits accruing to a State or political subdivision thereof as a land owner and, (b) the benefits accruing to the general public. Private interest is defined as the benefits derived by individuals or non-public groups of individuals on account of ownership of lands and business enterprises affected. All estimated benefits are classified as non-Federal public benefits.

39. Allocation of Costs. - Public Law 826, 84th Congress, established a policy of Federal aid in the restoration and protection of shores of the United States, its territories and possessions. The maximum Federal share of the cost is one-third of the first cost of construction and applies in the case of publicly-owned shores. The shores involved in the plans for Brant Rock and Plymouth Town Beach are publicly owned and are eligible for maximum Federal aid of one-third of the first cost. The raising of the jetty at Branch Rock and the provision of groins at Plymouth are intended to reduce losses of sand and are included in lieu of periodic nourishment alone. In these circumstances the periodic nourishment is not considered as construction eligible for Federal aid. The estimated allocations of cost are summarized on the following page.

Allerton Hill rise to a maximum height of about 110 feet in about the center of the southerly 1,000 feet of reach.

- h. Protective Structures: About 1,470 feet of concrete seawall (12), with 12-inch lip, in fair to good condition, 1,202 feet of granite block seawall (13) in good condition, and followed by about 1,000 feet with no structures, except for deteriorated timber bulkhead; about 50 feet long near southwest end of granite seawall.
- i. Character of Development: Large to average size residences.

(5) Nantasket Beach (north):

- a. Location: Allerton Hill to Metropolitan District Commission Beach. (X Street to Bay Street)
- b. Shore Length: Approximately 11,000 feet.
- c. Beach Width above H.W.: 100 to 175 feet.
- d. Ownership: Private backshore, town maintained beaches.
- e. Beach Use: Bathing.
- f. Public Facilities: Life guard service, rubbish containers, water fountains.
- g. Composition of Shore: Fine sand foreshore with shingle backshore at north end with shingle decreasing southward. Southerly 1-1/4 mile contains very small amount of shingle.
- h. Protective Structures: Low dunes on backshore disappearing near southerly end, intermittent concrete seawalls in low areas between dunes.
- i. Character of Development: Residential.

(6) Nantasket Beach (Metropolitan District Commission):

- a. Location: North from Atlantic Hill. (Bay Street to Atlantic Hill)
- b. Shore Length: Approximately 5,700 feet.
- c. Beach Width above H.W.: 25 to 100 feet.
- d. Ownership: Public.
- e. Beach Use: Bathing.
- f. Public Facilities: Bath house, eating facilities, parking areas and pavilions. Also a privately owned public bath house at south end.
- g. Composition of Beach: Fine sand with some gravel cover. Gravel periodically removed by MDC.
- h. Protective Structures: 300 feet placed stone revetment (14), 75 feet concrete seawall (15), 500 feet stone revetment (16), remainder of reach has concrete seawall (17) with walkway along top.
- i. Character of Development: Bathing facilities along beach and commercial eating and recreation facilities west of Nantasket Avenue.

(7) Atlantic Hill:

- a. Location: Nantasket Beach to Gun Rock Beach.
- b. Shore Length: Approximately 2,200 feet.
- c. Beach Width above H.W.: None
- d. Ownership: Private.
- e. Beach Use: Residential fishing and very limited bathing.
- f. Public Facilities: None
- g. Composition of Shore: Granite outcrop with bluffs to 70 feet in height.
- h. Protective Structures: None
- i. Character of Development: Residential.

(8) Gun Rock Beach:

- a. Location: South from Atlantic Hill fronting Straits Pond.
- b. Shore Length: Approximately 1,000 feet.
- c. Beach Width: Above H.W.: 10 feet at north to 125 feet at south.
- d. Ownership: Private with Town maintained beach for public usage.
- e. Beach Use: Public bathing and boating.
- f. Public Facilities: Trash Disposal.
- g. Composition of Shore: Fine sand with minor amount of gravel.
- h. Protective Structures: About 800 feet of stone seawall (18) with hand rail fronting street for north 300 feet and fronting houses to south.
- i. Character of Development: Residential.

(9) Crescent Beach (Atlantic Avenue Beach):

- a. Location: Gun Rock to Green Hill.
- b. Shore Length: Approximately 3,000 feet.
- c. Beach Width Above H.W.: Northerly 700 feet rocky with gravel beach of 0 width at H.W. 1,500 beach width 5-10 feet width, remainder 0 beach width.
- d. Ownership: Privately owned backshore, town maintained beach.
- e. Beach Use: Rocky areas for fishing, limited residential bathing on beach area.
- f. Public Facilities: None.
- g. Composition of Shore: Northerly 700 feet bed rock with gravel beach in bight, 1500 feet pea gravel to coarse gravel, southerly 800 feet bed rock outcrop with boulder bar.
- h. Protective Structures: North 700 feet-concrete seawall (20) 200 feet long in bight; 2300 feet of concrete seawall (21) from rock outcrop at west to outcrop at east, about 175 feet overturned in March 1956 storm & wall undermined at various points, spur jetties at 100 ft intervals

(2) Wellrock Beach:

- a. Location: Small bight between the Glades and north Scituate Beach.
- b. Shore Length: Approximately 400 feet.
- c. Beach Width above H.W.: About 100 feet.
- d. Ownership: Private
- e. Beach Use: Resident bathing.
- f. Public Facilities: None
- g. Composition of Shore: Fine Sand.
- h. Protective Structures: About 300 feet of stone masonry wall (30) with top about 6-8 feet above beach.
- i. Character of Development: Summer residences.

(3) North Scituate Beach (north):

- a. Location: Wellrock Beach to Gannet Road
- b. Shore Length: Approximately 2,200 feet.
- c. Beach Width above H.W.: 75 to 100 feet.
- d. Ownership: 1,800 feet of beach owned by Scituate Beach Association (for residents only) and 400 feet at north end private. Backshore west of street privately owned.
- e. Beach Use: Bathing Beach.
- f. Public Facilities: Life Guard service, trash receptacles.
- g. Composition of Shore: Fine sand with insignificant amount of gravel.
- h. Protective Structures: Concrete and stone masonry seawall (31) with low spur jetties about 30 feet long. In most cases spur jetties covered by sand. In vicinity of Cliff House Hotel there is about 300 feet of retaining wall above seawall.
- i. Character of Development: Fairly large residences and one hotel.

(4) North Scituate Beach (center):

- a. Location: Gannet Road to end of seawall.
- b. Shore Length: Approximately 2,700 feet.
- c. Beach Width above H.W.: 100 ft at north to 50 feet.
- d. Ownership: Private.
- e. Beach Use: Resident bathing.
- f. Public Facilities: None
- g. Composition of Shore: Fine sand with some gravel at north, becoming more gravelly until about midway all gravel except near HW, south end all gravel.
- h. Protective Structures: Concrete seawall (32) throughout with spur jetties at about 100 foot intervals. Wall in poor to fair condition at

north and fair condition at south. Except at north end jetties generally damaged.

- i. Character of Development: Average size summer residences.

(5) North Seituate Beach (south) (Includes portion of area known as Mann Hill Beach):

- a. Location: End of seawall to 700 feet south of Stone Ave.
- b. Shore Length: Approximately 3,800 feet.
- c. Beach Width above H.W.: This area consists of a gravel or shingle barrier 50 to 75 feet wide at the top and about 150 feet wide at H.W.
- d. Ownership: 700 feet Public (town), remainder private.
- e. Beach Use: Bathing.
- f. Public Facilities: None
- g. Composition of Shore: Gravel and shingle.
- h. Protective Structures: None
- i. Character of Development: Undeveloped except for about four summer cottages on top of barrier near center of reach.

(6) Mann Hill Beach and Shore Acres: (Portion of each)

- a. Location: Egypt town beach to Standish Ave.,
- b. Shore Length: Approximately 2,000 ft.
- c. Beach Width above H.W.: 50 ft at north to 15 feet at south.
- d. Ownership: Private.
- e. Beach Use: Resident Bathing.
- f. Public Facilities: None
- g. Composition of Shore: Shingle, evidently continuation of gravel barrier.
- h. Protective Structures: None
- i. Character of Development: Residential.

(7) Shore Acres and Hatherly Beach:

- a. Location: Standish Avenue to 2,400 feet south.
- b. Shore Length: Approximately 2,400 feet.
- c. Beach Width above H.W.: Approximately 10 feet at north to 50 feet at south.
- d. Ownership: Private.
- e. Beach Use: Resident Bathing
- f. Public Facilities: None
- g. Composition of Shore: Shingle and cobble.
- h. Protective Structures: North 700 feet stone revetment (53), good condition but light; remainder concrete seawall (34).
- i. Character of Development: Above average to average summer residences.

- e. Beach Use: Bathing and residential.
- f. Public Facilities: Access openings and right-of-way to beach.
- g. Composition of Shore: Northerly 4,500 consists of fine sand with some shingle and cobble at toe of seawall. Southerly 2,500 feet gravel and cobble bar.
- h. Protective Structures: 5,500 feet of concrete seawall (48, 49) with 25-foot long spurs at about 50-foot intervals with riprap along southerly 1,000 feet, 1500 feet of heavy stone revetment (50).
- i. Character of Development: Summer residences.

(3) Brant Rock Beach:

- a. Location: Northerly jetty to Brant Rock jetty.
- b. Shore Length: Approx. 2,700 feet.
- c. Beach Width above H.W.: 20 to 50 feet.
- d. Ownership: Public beach with street on backshore at northerly end and private residences behind seawall at south.
- e. Beach Use: Public bathing.
- f. Public Facilities: Steps from seawall to beach, limited parking area, trash receptacles, life guard service.
- g. Composition of Shore: Fine brown sand with some gravel adjacent to wall at each end.
- h. Protective Structures: Concrete seawall (53) except at northerly 150 feet of reach. Wall in fair to good condition except for about 115 feet of wall in front of abandoned Coast Guard property (now town owned) which is in bad condition. Two stone jetties (51, 52) in good condition about 450 and 800 feet long are located at each end of reach. Two groins (54, 55) in good condition, about 200 feet long, are about equally spaced between jetties. About 600 feet of grouted stone revetment (56) south from groin (54).
- i. Character of Development: Summer residences behind street at north end and between seawall and street at south end.

(4) Brant Rock to Green Harbor:

- a. Location: North from Green Harbor River.
- b. Shore Length: Approx. 4,500 feet.
- c. Beach Width above H.W.: None
- d. Ownership: Private, except 141 feet south from Brant Rock jetty owned by town.
- e. Beach Use: Restricted bathing.
- f. Public Facilities: None
- g. Composition of Shore: Revetment fronting cobble bars. Backshore sand and glacial till.

- h. Protective Structures: 700 feet concrete seawall (57), 1,200 feet stone revetment (58), 1,000 feet concrete seawall (59), 1,200 feet stone revetment (60), the remainder unprotected except for a stone groin and two (2) concrete groins adjacent to the north side of the navigation jetty at south end. All in fair to good condition.
- i. Character of Development: Medium priced residences and a tent and trailer camp located about 1,500 feet from south end.

(5) Green Harbor Area:

- a. Location: South from Green Harbor south jetty.
- b. Shore Length: Approx. 3,000 feet.
- c. Beach Width above H.W.: 75 feet to 25 feet.
- d. Ownership: Public (town).
- e. Beach Use: Bathing.
- f. Public Facilities: Parking area (fee), rubbish disposal facilities, life guard service.
- g. Composition of Shore: Fine gray sand.
- h. Protective Structures: 1,100 feet of low concrete seawall (63) well back from beach at south end of reach.
- i. Character of Development: Beach and parking lot.

E. Duxbury:

(1) Residential Area:

- a. Location: Duxbury town line to 4,300 feet south.
- b. Shore Length: Approximately 4,300 feet.
- c. Beach Width above H.W.: 20 to 30 feet.
- d. Ownership: Private limited public use of beach.
- e. Beach Use: Bathing.
- f. Public Facilities: None
- g. Composition: Fine gray sand with small amount of gravel between high and low water at south end.
- h. Protective Structures: Two lengths of about 750 feet and 1,575 feet of concrete seawall (64, 65) near north end of reach.
- i. Character of Development: Residential.

(2) Duxbury Beach:

- a. Location: North end Duxbury Beach Assoc. Park to Powder Point Bridge.
- b. Shore Length: Approximately 3,500 feet.
- c. Beach Width above H.W.: Approximately 60 feet.
- d. Ownership: Town administered by Duxbury Beach Assoc. Beach used publicly during week-days for parking fee. During Saturdays, Sundays and holidays residents only.
- e. Beach Use: Recreational beach.
- f. Public Facilities: Bath house (leased), paved parking facilities, Association maintained.

- h. Protective Structures: 700 feet concrete seawall (57), 1,200 feet stone revetment (58), 1,000 feet concrete seawall (59), 1,200 feet stone revetment (60), the remainder unprotected except for a stone groin and two (2) concrete groins adjacent to the north side of the navigation jetty at south end. All in fair to good condition.
- i. Character of Development: Medium priced residences and a tent and trailer camp located about 1,500 feet from south end.

(5) Green Harbor Area:

- a. Location: South from Green Harbor south jetty.
- b. Shore Length: Approx. 3,000 feet.
- c. Beach Width above H.W.: 75 feet to 25 feet.
- d. Ownership: Public (town).
- e. Beach Use: Bathing.
- f. Public Facilities: Parking area (fee), rubbish disposal facilities, life guard service.
- g. Composition of Shore: Fine gray sand.
- h. Protective Structures: 1,100 feet of low concrete seawall (63) well back from beach at south end of reach.
- i. Character of Development: Beach and parking lot.

E. Duxbury:

(1) Residential Area:

- a. Location: Duxbury town line to 4,300 feet south.
- b. Shore Length: Approximately 4,300 feet.
- c. Beach Width above H.W.: 20 to 30 feet.
- d. Ownership: Private limited public use of beach.
- e. Beach Use: Bathing.
- f. Public Facilities: None
- g. Composition: Fine gray sand with small amount of gravel between high and low water at south end.
- h. Protective Structures: Two lengths of about 750 feet and 1,575 feet of concrete seawall (64, 65) near north end of reach.
- i. Character of Development: Residential.

(2) Duxbury Beach:

- a. Location: North end Duxbury Beach Assoc. Park to Powder Point Bridge.
- b. Shore Length: Approximately 3,500 feet.
- c. Beach Width above H.W.: Approximately 60 feet.
- d. Ownership: Town administered by Duxbury Beach Assoc. Beach used publicly during week-days for parking fee. During Saturdays, Sundays and holidays residents only.
- e. Beach Use: Recreational beach.
- f. Public Facilities: Bath house (leased), paved parking facilities, Association maintained.

- c. Beach Width above H.W.: 75 feet to 0 for 2,200 feet; 0 for 2,300 feet; 10 to 15 feet for 2,300; then, variable, 15 to 50 feet fronting dunes for remainder and about 100 feet on the end of spit.
- d. Ownership: Public (town) except for few cottage sites.
- e. Beach Use: Recreational and protection for Plymouth Harbor.
- f. Beach Facilities: None
- g. Composition of Shore: Medium to fine sand mixed with some gravel except at northernmost end where gravel is not visible.
- h. Protective Structures: Stone dike (66) about 12,000 feet in length; stone jetty (66a) about 150 feet in length at outer end; low stone revetment (66b) about 3,500 feet in length; and a low stone groin (66c) about 100 feet long on the harbor side of the spit.
- i. Character of Development: Undeveloped.

(3) Plymouth (Long) Beach:

- a. Location: Root of spit, between Long Beach dike and Town Beach seawall (67).
- b. Shore Length: 1,200 feet.
- c. Beach Width above H.W.: 75 feet at north to 50 feet at seawall.
- d. Ownership: Private
- e. Beach Use: Recreation (bathing)
- f. Beach Facilities: None
- g. Composition of Shore: Medium to fine sand with some gravel.
- h. Protective Structures: None
- i. Character of Development: Medium size homes behind beach.

(4) Plymouth Town Beach:

- a. Location: Warren Cove
- b. Shore Length: 1,300 feet.
- c. Beach Width above H.W.: 50 feet at north end of seawall to 0 feet at south end of bathhouse and no beach width southward to end of reach.
- d. Ownership: Public: Town of Plymouth.
- e. Beach Use: Public bathing beach.
- f. Beach Facilities: Bathhouse, parking facilities, etc.
- g. Composition of Shore: Above HW fine sand adjacent to seawall to bathhouse then mixed with gravel from thereon to south end. Below HW medium to coarse sand mixed with gravel, also small cobble at south end.
- h. Protective Structures: 900 feet of new concrete seawall (67) with stone apron beneath beach from

- g. Composition of Shore: Bluffs 30 to 60 feet high of sand and small amount of clay. Beach of gravel with very little sand.
- h. Protective Structures: Stone mound revetment (71) constructed April 1957.
- i. Character of Development: Medium to large residences.

(8) Rocky Point:

- a. Location: Adjacent to reach (7) to northerly point.
- b. Extent: About 8,000 feet.
- c. Beach Width above H.W.: Cobble and boulder bar ranging in width from about 50 to 75 feet.
- d. Ownership: Private.
- e. Beach Use: Limited residential use.
- f. Beach Facilities: None
- g. Composition of Shore: Bluffs 60 to 100 feet high composed of sand with gravel and large boulders with short segments of clay.
- h. Protective Structures: None
- i. Character of Development: Medium to large residences.

(9) Rocky Point:

- a. Location: Adjacent to reach (8)
- b. Extent: About 4,100 feet.
- c. Beach Width above H.W.: Cobble and boulder bar 50 to 60 feet in width along north half, gravel and cobble with some coarse sand ranging from 50 to 100 feet in width along southerly half.
- d. Ownership: Private.
- e. Beach Use: Limited resident bathing along southerly portion.
- f. Beach Facilities: None
- g. Composition of Shore: Glacial till bluffs 50 to 60 feet high along northerly 2,000 feet, southerly portion low, flat glacial till area.
- h. Protective Structures: Short cobble revetment fronting a house near south end.
- i. Character of Development: Northerly portion contained rather widely spaced medium cost residences, southerly portion undeveloped except for one summer residence.

(10) Rocky Point:

- a. Location: Adjacent to reach (9) and north of White Horse Beach.
- b. Extent: 3,200 feet.
- c. Beach Width above H.W.: Boulder bar about 50 feet in width.
- d. Ownership: Private.
- e. Beach Use: Limited if any.
- f. Beach Facilities: None

- g. Composition of Shore: Sand bluffs 20 to 90 feet in height with cobble and boulder bar at toe.
- h. Protective Structures: None
- i. Character of Development: Medium priced residences.

(11) Priscilla and White Horse Beaches:

- a. Location: Adjacent to reach (10)
- b. Extent: 4,000 feet
- c. Beach Width above H.W.: 25 feet at north end, increasing to 50 feet about middle and remaining about that width throughout remainder.
- d. Ownership: Private.
- e. Beach Use: Bathing and boating generally limited to residents of the area and of Manomet Sportsmen Club.
- f. Beach Facilities: None
- g. Composition of Shore: Fine sand mixed with gravel at north end, gravel disappearing near center of reach, then becoming coarse sand near south end, fine gravel at Bartlett Pond outlet. Low dunes behind beach.
- h. Protective Structures: Seven stone groins about 200 feet apart at south end. Groins appear to be generally collecting wind blown sand. Scattered private low walls and revetment fronting individual lots. Stone revetment extending from pond outlet and along Manomet Sportsmen Club property.
- i. Character of Development: Small summer cottages along most of shore (probably rental). Few larger summer residences at north end. Manomet Sportsmen Club at south end.

(12) White Horse Beach:

- a. Location: Bartlett Pond outlet to Manomet Point.
- b. Extent: 3,500 feet.
- c. Beach Width above H.W.: Varying - 35 to 75 feet.
- d. Ownership: Private.
- e. Beach Use: Resident and Hotel bathing beach.
- f. Beach Facilities: Private beach club house and bath house, Hotel Mayflower bath house at south end.
- g. Composition of Shore: Fine sand with small amount of gravel above high water, below high water fine at north becoming coarse at south. Low dunes, generally receding behind beach. Meandering stream (Bartlett Pond) outlet about 5 feet wide and 1-2 feet deep running through beach at north end.
- h. Protective Structures: Several scattered timber bulkheads fronting individual lots.

- i. Character of Development: Generally small cottages and above mentioned beach facilities. One private beach club and one hotel.

(13) Manomet Point:

- a. Location: Adjacent to reach (12).
- b. Extent: 1,500 feet.
- c. Beach Width above H.W.: 25-35 feet.
- d. Ownership: Private
- e. Beach Use: Limited. Some fishing.
- f. Beach Facilities: None
- g. Composition of Shore: Glacial till bluff 40 to 50 feet high with cobble and boulder bar at toe. Erosion of bluff apparent along west 200 feet.
- h. Protective Structures: About 1,200 feet of stone mound revetment beginning 200 feet from west end of reach. Two short stone jetties about 100 feet apart and fronting a small fish wharf at south end.
- i. Character of Development: Scattered small summer cottages and small seasonal commercial fish wharf at south end.

(14) Manomet Point to Stage Point:

- a. Location: Between points.
- b. Extent: 1,800 feet.
- c. Beach Width above H.W.: None
- d. Ownership: Private.
- e. Beach Use: Fishing & boating.
- f. Beach Facilities: None
- g. Composition of Shore: Glacial till bluffs 30 to 50 feet high with fine sand, boulders and cobble at toe. Severe erosion of bluffs apparent.
- h. Protective Structures: Revetment (83) consisting principally of boulders and stone from past erosion of bluff.
- i. Character of Development: Medium to large summer homes.

(15) Stage Point:

- a. Location: West from point.
- b. Extent: 2,100 feet.
- c. Beach Width above H.W.: None
- d. Ownership: Private
- e. Beach Use: Limited use, some fishing and boating.
- f. Beach Facilities: None
- g. Composition of Shore: Glacial till bluffs up to 70 feet in height fronted by fine to medium sand, gravel, cobble and boulders.
- h. Protective Structures: Boulder revetment about 750 feet long. Two stone groins (84, 85) about 100 and 125 feet long and 600 feet apart at

- i. Character of Development: Generally small cottages and above mentioned beach facilities. One private beach club and one hotel.

(13) Manomet Point:

- a. Location: Adjacent to reach (12).
b. Extent: 1,500 feet.
c. Beach Width above H.W.: 25-35 feet.
d. Ownership: Private
e. Beach Use: Limited. Some fishing.
f. Beach Facilities: None
g. Composition of Shore: Glacial till bluff 40 to 50 feet high with cobble and boulder bar at toe. Erosion of bluff apparent along west 200 feet.
h. Protective Structures: About 1,200 feet of stone mound revetment beginning 200 feet from west end of reach. Two short stone jetties about 100 feet apart and fronting a small fish wharf at south end.
i. Character of Development: Scattered small summer cottages and small seasonal commercial fish wharf at south end.

(14) Manomet Point to Stage Point:

- a. Location: Between points.
b. Extent: 1,800 feet.
c. Beach Width above H.W.: None
d. Ownership: Private.
e. Beach Use: Fishing & boating.
f. Beach Facilities: None
g. Composition of Shore: Glacial till bluffs 30 to 50 feet high with fine sand, boulders and cobble at toe. Severe erosion of bluffs apparent.
h. Protective Structures: Revetment (83) consisting principally of boulders and stone from past erosion of bluff.
i. Character of Development: Medium to large summer homes.

(15) Stage Point:

- a. Location: West from point.
b. Extent: 2,100 feet.
c. Beach Width above H.W.: None
d. Ownership: Private
e. Beach Use: Limited use, some fishing and boating.
f. Beach Facilities: None
g. Composition of Shore: Glacial till bluffs up to 70 feet in height fronted by fine to medium sand, gravel, cobble and boulders.
h. Protective Structures: Boulder revetment about 750 feet long. Two stone groins (84, 85) about 100 and 125 feet long and 600 feet apart at

(18) Indian Hill:

- a. Location: Indian Brook to Ship Pond.
- b. Extent: About 8,000 feet.
- c. Beach Width above H.W.: 40 feet at north to 0 at center to 10-20 feet at south.
- d. Ownership: Private.
- e. Beach Use: Limited residential use.
- f. Beach Facilities: None
- g. Composition of Shore: Sand bluffs ranging from 50 to 120 feet in height with scattered strata of blue clay. Cobble and boulder beach above HW and cobble mixed with sand below. Scattered areas of active erosion apparently generally caused by surface runoff flattening slope steepened by wave attack at toe.
- h. Protective Structures: Private timber bulkhead fronting a single lot near south end.
- i. Character of Development: Summer cottages.

(19) Ship Pond Barrier:

- a. Location: Ship Pond at Vallersville.
- b. Extent: 1,300 feet.
- c. Beach Width above H.W.: About 200 feet between groins and 25 to 50 feet south thereof.
- d. Ownership: Private.
- e. Beach Use: Boat yard (repair and construction) at north end.
- f. Beach Facilities: None
- g. Composition of Shore: Dune between pond and beach. Between groins medium to coarse sand, and south thereof fine sand above H.W. Coarse sand and gravel from H.W. to about 2 feet above L.W. then cobble bar.
- h. Protective Structures: Two stone groins (95 and 96) each about 200 feet long and 150 feet apart at north end of reach. Groins effective in holding sand above level of both sides of compartment.
- i. Character of Development: Commercial establishment at north end includes facilities for repair of fishing traps, repair and construction of boats, contains marine railway, storage and working sheds. Two small summer cottages at south end, remainder undeveloped.

(20) North of Center Hill Point:

- a. Location: South from Ship Pond.
- b. Extent: 3,300 feet.
- c. Beach Width above H.W.: 50 feet at north increasing to about 100 feet near center then decreasing to about 25 feet at south end. Beach very flat above HW.

- d. Ownership: Private.
- e. Beach Use: Bathing by residents.
- f. Beach Facilities: None
- g. Composition of Shore: Medium sand above high water at north end becoming medium to coarse at mouth. Below HW coarse sand and gravel. Sand bluffs behind beach range from 20 to 50 feet in height. Beach above HW very flat, about 1 on 10 slope between HW and 1 to 2 feet above LW, and cobble and boulder bar at south end of reach.
- h. Protective Structures: Two stone groins (97, 98) the most southerly of which is located about 1,100 feet north of south end of reach. The groins have widened the beach but have not prevented sloughing of the bluff. Bluff damage occurring throughout the reach.
- i. Character of Development: Medium size summer cottages along shore.

(21) Center Hill Point:

- a. Location: Adjacent to reach (20)
- b. Extent: 1,000 feet.
- c. Beach Width above H.W.: 20 - 40 feet.
- d. Ownership: Private.
- e. Beach Use: Resident Use.
- f. Beach Facilities: None
- g. Composition of Shore: Cobble above HW and below elevation of mid-tide, coarse sand and gravel between. Glacial till bluff about 50 feet in height behind beach.
- h. Protective Structures: None - Bluff eroding.
- i. Character of Development: Summer residences.

(22) Center Hill Pond Barrier:

- a. Location: South from Center Hill Point.
- b. Extent: 2,400 feet.
- c. Beach Width above H.W.: 25 to 50 feet.
- d. Ownership: Private.
- e. Beach Use: None
- f. Beach Facilities: None
- g. Composition of Shore: Medium sand mixed with cobble above HW, coarse sand and gravel below. Dune begins about center of reach and blends into bluff at south end.
- h. Protective Structures: None - Appears that storm waves overtop the barrier beach at north end.
- i. Character of Development: Undeveloped.

(23) Black Pond Area:

- a. Location: 2,400 to 4,400 feet north of Ellisville Harbor.
- b. Extent: 2,000 feet.

- c. Beach Width above H.W.: 25 to 50 feet updrift of groins (104-107) and 0 to 10 feet downdrift. Ranges from 0 to 25 feet in remainder of area.
- d. Ownership: Private.
- e. Beach Use: Resident bathing.
- f. Beach Facilities: None.
- g. Composition of Shore: Medium sand mixed with boulders above HW and coarse sand with gravel below. Bluff ranging from 30 feet in height at north end to 10 feet in height at south.
- h. Protective Structures: Ten low, timber groins (99-108) 75 to 150 feet long and 100 to 300 feet apart. Groins (99-103 and 108) ineffective due to deterioration. Concrete seawall facing 4 lots and timber bulkhead fronting 1 lot. Some erosion at north end.
- i. Character of Development: Medium summer residences.

(24) North of Ellisville Harbor:

- a. Location: Adjacent to north jetty
- b. Extent: 2,400 feet.
- c. Beach Width above H.W.: Varying - 50 to 100 feet.
- d. Ownership: Private.
- e. Beach Use: Resident bathing.
- f. Beach Facilities: None
- g. Composition of Shore: Medium to coarse sand above HW and coarse sand to fine gravel below. Northerly 700 feet backed by bluff 70 feet in height, remainder rather low and flat.
- h. Protective Structures: Stone revetment fronting one lot near north end. Bluff damage at north end. Ellisville Harbor stone jetty (109) about 250 feet long at south end.
- i. Character of Development: Medium summer residences along north 700 feet, remainder undeveloped.

(25) Lookout Point:

- a. Location: Ellisville Harbor to about 1,300 feet south of Lookout Point.
- b. Extent: 3,600 feet.
- c. Beach Width above H.W.: Updrift side of groins ranges from 125 feet at north end to 0 at south end. Downdrift of groins ranges from 100 feet at north to 0 at south.
- d. Ownership: Private.
- e. Beach Use: Resident bathing.
- f. Beach Facilities: None
- g. Composition of Shore: Medium sand above HW and medium sand and gravel below.
- h. Protective Structures: 6 stone groins (110-115) 200 feet long and 1 stone groin (116) 80 feet

- c. Beach Width above H.W.: 25 to 50 feet updrift of groins (104-107) and 0 to 10 feet downdrift. Ranges from 0 to 25 feet in remainder of area.
- d. Ownership: Private.
- e. Beach Use: Resident bathing.
- f. Beach Facilities: None.
- g. Composition of Shore: Medium sand mixed with boulders above HW and coarse sand with gravel below. Bluff ranging from 30 feet in height at north end to 10 feet in height at south.
- h. Protective Structures: Ten low, timber groins (99-108) 75 to 150 feet long and 100 to 300 feet apart. Groins (99-103 and 108) ineffective due to deterioration. Concrete seawall facing 4 lots and timber bulkhead fronting 1 lot. Some erosion at north end.
- i. Character of Development: Medium summer residences.

(24) North of Ellisville Harbor:

- a. Location: Adjacent to north jetty
- b. Extent: 2,400 feet.
- c. Beach Width above H.W.: Varying - 50 to 100 feet.
- d. Ownership: Private.
- e. Beach Use: Resident bathing.
- f. Beach Facilities: None
- g. Composition of Shore: Medium to coarse sand above HW and coarse sand to fine gravel below. Northerly 700 feet backed by bluff 70 feet in height, remainder rather low and flat.
- h. Protective Structures: Stone revetment fronting one lot near north end. Bluff damage at north end. Ellisville Harbor stone jetty (109) about 250 feet long at south end.
- i. Character of Development: Medium summer residences along north 700 feet, remainder undeveloped.

(25) Lookout Point:

- a. Location: Ellisville Harbor to about 1,300 feet south of Lookout Point.
- b. Extent: 3,600 feet.
- c. Beach Width above H.W.: Updrift side of groins ranges from 125 feet at north end to 0 at south end. Downdrift of groins ranges from 100 feet at north to 0 at south.
- d. Ownership: Private.
- e. Beach Use: Resident bathing.
- f. Beach Facilities: None
- g. Composition of Shore: Medium sand above HW and medium sand and gravel below.
- h. Protective Structures: 6 stone groins (110-115) 200 feet long and 1 stone groin (116) 80 feet

- i. Character of Development: Medium to large summer residences.

G. Town of Bourne:

(1) Sagamore Highlands:

- a. Location: Peaked Cliff area.
- b. Extent: 3,500 feet.
- c. Beach Width above H.W.: 80 feet to about 130 feet at center to about 150 feet at south end.
- d. Ownership: Private.
- e. Beach Use: Resident bathing.
- f. Beach Facilities: None
- g. Composition of Shore: Medium to fine sand above HW and coarse sand mixed with gravel below. Few boulders in northerly 900 feet of shore. Sand bluff to 150 feet high back of beach.
- h. Protective Structures: None
- i. Character of Development: Medium residences on bluff.

(2) Sagamore Beach:

- a. Location: South from Peaked Cliff.
- b. Extent: 3,300 feet.
- c. Beach Width above H.W.: From north end to updrift of groin (123) about 100 feet wide and 85 feet wide downdrift of groins (121-122). Downdrift of groin (123) decreases to 50 feet. Groins (124-128) 50 feet on updrift side, 40 feet on downdrift.
- d. Ownership: Private.
- e. Beach Use: Resident bathing.
- f. Beach Facilities: None
- g. Composition of Shore: At groin (121) fine to medium sand above HW and coarse below, becoming coarser to south. At groin (128) gravel with some sand above HW and shingle and cobble below.
- h. Protective Structures: 8 stone groins (121-128) about 175 feet long and 400 feet apart. Three upper groins effective and five southerly somewhat starved. Groins (124-128) damage at about HW line on beach.
- i. Character of Development: Medium to large summer residences and one small hotel near north end.

(3) Sagamore Beach:

- a. Location: Groin system to Sandwich Town Line.
- b. Extent: 1,900 feet.
- c. Beach Width above H.W.: 40 feet downdrift of groin (128) increasing at a point 500 feet south to 100 to 125 feet fronting dunes.
- d. Ownership: Private.

3. Differences in tide heights at various points along the coast have been determined by the United States Coast and Geodetic Survey, by means of relatively short term periods of observation, and related to Boston heights for convenience in predicting tide heights at these locations. These tide differences and heights are shown in Table B-2. The locations of these areas are shown on Plate 1.

Table B-2 Tidal Differences and Ranges

Location	Position		Differences From Boston Tides			Ranges in Feet	
	Lat.	Long.	Time In hours	Height in Feet		Mean	Spring
				High	Low		
Boston	42° 21'	71° 03'	-	-	-	9.5	11.0
Nantasket Weir River	42° 16'	70° 52'	✓0.05	-0.1	0.0	9.4	10.9
Strawberry Hill	42° 17'	70° 53'	✓0.05	0.0	0.0	9.5	11.0
Hull	42° 18'	70° 55'	✓0.05	-0.3	0.0	9.2	10.7
Cohasset Harbor	42° 15'	70° 47'	0.00	-0.7	0.0	8.8	10.2
Scituate	42° 12'	70° 43'	0.00	-0.5	0.0	9.0	10.4
Gurnet Point	42° 00'	70° 36'	✓0.05	-0.3	0.0	9.2	10.7
Plymouth	41° 58'	70° 40'	✓0.10	✓0.1	0.0	9.6	11.1
Cape Cod Canal Entrance	41° 46'	70° 30'	✓0.05	-0.1	0.0	9.4	10.9
Barnstable Harbor (Beach Pt.)	41° 43'	70° 17'	✓0.20	0.0	0.0	9.5	11.0

4. Storm Tides. - High velocity winds increase tides in varying amounts depending upon direction and severity of the winds and upon the hydrography of the nearshore and shelter of the location. The tides, of course, raise the elevation of the water surface so that the waves may cause greater damage to the shore. Table B-3 shows maximum elevations recorded at Boston during recent storms. Table B-4 gives elevations of record prior to 1933. Elevations shown for storms prior to March 1931 were observed at points other than Commonwealth Pier and are therefore not directly comparable to the more recent observations.

APPENDIX C

WINDS, WAVES AND STORMS

1. Prevailing Winds. United States Weather Bureau wind records for Boston, Massachusetts, the weather station located nearest to the study area, are available for the period October 1949 through September 1956. These data consist of hourly observations of wind speed and direction based on sixteen points of the compass. A wind rose made from these records is shown on Plate 1.

2. The wind rose indicates a preponderance of westerly winds with the greatest duration from the southwest. However, by combining winds within quadrants it is shown that prevailing winds are from the northwest quadrant. The study area faces open water to the east, therefore the wave action affecting the shore can be generated only by winds having easterly components. Predominant winds from the easterly directions are shown as having about equal duration from the two quadrants with peaks at the northeast, east and east-southeast directions. It may be concluded that prevailing winds are from westerly directions or offshore with respect to the study area and that predominant onshore winds are from the east and northeast.

3. Waves. - No wave observations have been made along the coast, in the study area. The wave characteristics discussed herein were obtained by hindcast methods and are presented in Beach Erosion Board Technical Memorandum No. 55, entitled "North Atlantic Coast Wave Statistics Hindcast by Bretschneider - Revised Sverdrup-Munk Method." The coast of the study area is exposed to deep water waves which are generated by winds from the easterly quadrants. The study area is exposed to ocean waves generated over long fetches from directions of north to east. From the directions of north to northwest the fetch is limited by Boston Harbor, and Cape Cod limits the fetch for directions of east to south-southeast. A wave rose prepared from hindcast data is included on Plate 1.

4. Hindcasts have been made for a station in deep water off Nauset Beach, Cape Cod, Massachusetts, about 70 miles east-southeast of the center of the study area (see Plate 1 for location). A summary of hours of occurrence of waves from the effective directions is shown on Table C-2. From both the table and the wave rose, it may be seen that the predominant direction of approach is from the east and the east-northeast directions.

5. Storms. - Hurricanes can be defined as tropical cyclones with a central barometric pressure of 29.0 inches or less and winds near the center 75 miles per hour or more in some points in the path. In the northern hemisphere they are known to consist of winds revolving in a counter-clockwise direction about a calm center or "eye". This calm center has an average diameter of approximately 14 miles. The diameter of hurricanes varies considerably, some being 50 to 75 miles; the majority greater, in many instances exceeding 500 miles. Winds at the outer limits are usually light increasing to moderate and gusty toward the center, and they blow with great

Wind Data - Boston, Massachusetts - Logan International Airport
October 1949 - September 1956 (7 Year Record)

Table C-1

Wind Data

Directions	Speed Miles per Hour										% Total	Avg.	Wind	% Total
											Duration	Speed	Movement	Movement
											M.P.H.	(Miles)		
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	Over 47	Total				
N	73	464	1211	909	271	89	13	2	0	3032	4.9	12.4	37,481	4.7
NNE	56	305	707	598	307	130	27	5	1	2136	3.5	13.8	29,475	3.7
NE	72	410	770	755	424	166	74	30	11	2712	4.4	14.6	39,702	4.9
ENE	75	304	615	617	287	149	41	16	4	2108	3.5	14.3	30,181	3.8
E	68	366	1050	915	235	89	29	19	2	2773	4.5	12.9	35,852	4.4
ESE	66	446	1205	920	175	55	10	0	4	2881	4.7	11.7	33,707	4.2
SE	74	471	966	622	106	17	-	-	1	2257	3.7	10.9	24,585	3.1
SSE	49	427	818	342	60	21	3	2	1	1723	2.8	10.4	17,860	2.2
S	59	660	1168	686	181	47	10	3	-	2814	4.6	11.1	31,337	3.9
SSW	54	587	1520	1409	501	135	33	9	2	4250	6.9	13.2	56,103	7.0
SW	64	819	3242	3067	766	196	31	3	-	8188	13.4	13.0	106,375	13.2
WSW	48	453	1531	1388	314	70	15	0	-	3819	6.2	12.5	47,896	6.0
W	59	559	1683	1568	606	170	60	6	-	4711	7.7	13.7	64,448	8.0
WNW	57	761	2400	2447	1035	377	52	7	1	7137	11.6	14.1	100,652	12.5
NW	65	612	1806	2324	1092	404	58	4	2	6367	10.4	14.8	94,155	11.7
NNW	46	365	1353	1426	560	139	14	1	1	3905	6.4	13.7	53,617	6.7
Calms										486	0.8			
TOTAL										61299	100.0	12.9	803,426	100.0

APPENDIX C

WINDS, WAVES AND STORMS

1. Prevailing Winds. United States Weather Bureau wind records for Boston, Massachusetts, the weather station located nearest to the study area, are available for the period October 1949 through September 1956. These data consist of hourly observations of wind speed and direction based on sixteen points of the compass. A wind rose made from these records is shown on Plate 1.

2. The wind rose indicates a preponderance of westerly winds with the greatest duration from the southwest. However, by combining winds within quadrants it is shown that prevailing winds are from the northwest quadrant. The study area faces open water to the east, therefore the wave action affecting the shore can be generated only by winds having easterly components. Predominant winds from the easterly directions are shown as having about equal duration from the two quadrants with peaks at the northeast, east and east-southeast directions. It may be concluded that prevailing winds are from westerly directions or offshore with respect to the study area and that predominant onshore winds are from the east and northeast.

3. Waves. - No wave observations have been made along the coast, in the study area. The wave characteristics discussed herein were obtained by hindcast methods and are presented in Beach Erosion Board Technical Memorandum No. 55, entitled "North Atlantic Coast Wave Statistics Hindcast by Bretschneider - Revised Sverdrup-Munk Method." The coast of the study area is exposed to deep water waves which are generated by winds from the easterly quadrants. The study area is exposed to ocean waves generated over long fetches from directions of north to east. From the directions of north to northwest the fetch is limited by Boston Harbor, and Cape Cod limits the fetch for directions of east to south-southeast. A wave rose prepared from hindcast data is included on Plate 1.

4. Hindcasts have been made for a station in deep water off Nauset Beach, Cape Cod, Massachusetts, about 70 miles east-southeast of the center of the study area (see Plate 1 for location). A summary of hours of occurrence of waves from the effective directions is shown on Table C-2. From both the table and the wave rose, it may be seen that the predominant direction of approach is from the east and the east-northeast directions.

5. Storms. - Hurricanes can be defined as tropical cyclones with a central barometric pressure of 29.0 inches or less and winds near the center 75 miles per hour or more in some points in the path. In the northern hemisphere they are known to consist of winds revolving in a counter-clockwise direction about a calm center or "eye". This calm center has an average diameter of approximately 14 miles. The diameter of hurricanes varies considerably, some being 50 to 75 miles; the majority greater, in many instances exceeding 500 miles. Winds at the outer limits are usually light increasing to moderate and gusty toward the center, and they blow with great

Wind Data - Boston, Massachusetts - Logan International Airport
October 1949 - September 1956 (7 Year Record)

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Wind Data

Directions	Hours										% Total	Avg.	Wind	% Total
	Speed Miles per Hour										Duration	Speed	Movement	Movement
	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	Over 47	Total		M.P.H.	(Miles)	
N	73	464	1211	909	271	89	13	2	0	3032	4.9	12.4	37,481	4.7
NNE	56	305	707	598	307	130	27	5	1	2136	3.5	13.8	29,475	3.7
NE	72	410	770	755	424	166	74	30	11	2712	4.4	14.6	39,702	4.9
ENE	75	304	615	617	287	149	41	16	4	2108	3.5	14.3	30,181	3.8
E	68	366	1050	915	235	89	29	19	2	2773	4.5	12.9	35,852	4.4
ESE	66	446	1205	920	175	55	10	0	4	2881	4.7	11.7	33,707	4.2
SE	74	471	966	622	106	17	-	-	1	2257	3.7	10.9	24,585	3.1
SSE	49	427	818	342	60	21	3	2	1	1723	2.8	10.4	17,860	2.2
S	59	660	1168	686	181	47	10	3	-	2814	4.6	11.1	31,337	3.9
SSW	54	587	1520	1409	501	135	33	9	2	4250	6.9	13.2	56,103	7.0
SW	64	819	3242	3067	766	196	31	3	-	8188	13.4	13.0	106,375	13.2
WSW	48	453	1531	1388	314	70	15	0	-	3819	6.2	12.5	47,896	6.0
W	59	559	1683	1568	606	170	60	6	-	4711	7.7	13.7	64,448	8.0
WNW	57	761	2400	2447	1035	377	52	7	1	7137	11.6	14.1	100,652	12.5
NW	65	612	1806	2324	1092	404	58	4	2	6367	10.4	14.8	94,155	11.7
NNW	46	365	1353	1426	560	139	14	1	1	3905	6.4	13.7	53,617	6.7
Calms										486	0.8			
TOTAL										61299	100.0	12.9	803,426	100.0

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											M.P.H.	(Miles)		
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NNE	56	305	707	598	307	130	27	5	1	2136	3.5	13.8	29,475	3.7
NE	72	410	770	755	424	166	74	30	11	2712	4.4	14.6	39,702	4.9
ENE	75	304	615	617	287	149	41	16	4	2108	3.5	14.3	30,181	3.8
E	68	366	1050	915	235	89	29	19	2	2773	4.5	12.9	35,852	4.4
ESE	66	446	1205	920	175	55	10	0	4	2881	4.7	11.7	33,707	4.2
SE	74	471	966	622	106	17	-	-	1	2257	3.7	10.9	24,585	3.1
SSE	49	427	818	342	60	21	3	2	1	1723	2.8	10.4	17,860	2.2
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SW	64	819	3242	3067	766	196	31	3	-	8188	13.4	13.0	106,375	13.2
WSW	48	453	1531	1388	314	70	15	0	-	3819	6.2	12.5	47,896	6.0
W	59	559	1683	1568	606	170	60	6	-	4711	7.7	13.7	64,448	8.0
WNW	57	761	2400	2447	1035	377	52	7	1	7137	11.6	14.1	100,652	12.5
NW	65	612	1806	2324	1092	404	58	4	2	6367	10.4	14.8	94,155	11.7
NNW	46	365	1353	1426	560	139	14	1	1	3905	6.4	13.7	53,617	6.7
Calms										486	0.8			
TOTAL										61299	100.0	12.9	803,426	100.0

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NE	72	410	770	755	424	166	74	30	11	2712	4.4	14.6	39,702	4.9
ENE	75	304	615	617	287	149	41	16	4	2108	3.5	14.3	30,181	3.8
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NNW	46	365	1353	1426	560	139	14	1	1	3905	6.4	13.7	53,617	6.7
Calms										486	0.8			
TOTAL										61299	100.0	12.9	803,426	100.0

Table C-2. Hours of Wave Occurrence During 3-Year Period 1948 - 1950

Range of Wave Height (feet)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	TOTAL
25-30		4 (4)	12 (12)	28 (28)	12 (12)		4 (4)					60 (60)
20-25		12 (16)	20 (32)	84 (112)	24 (36)	4 (4)	4 (8)					148 (208)
18-20		8 (24)	16 (48)	24 (136)	28 (64)	4 (8)	4 (12)			12 (12)	12 (12)	108 (316)
16-18	8 (8)	16 (40)	12 (60)	112 (248)	68 (132)	16 (24)	12 (24)			8 (20)	4 (16)	256 (572)
14-16	12 (20)	20 (60)	24 (84)	132 (380)	96 (228)	20 (44)	16 (40)	8 (8)	12 (12)	8 (28)	20 (36)	368 (940)
12-14	16 (36)	16 (76)	28 (112)	220 (600)	112 (340)	32 (76)	24 (64)	8 (16)	36 (48)	8 (36)	24 (60)	524 (1464)
10-12	56 (92)	136 (212)	24 (136)	280 (880)	188 (528)	84 (160)	32 (96)	64 (80)	76 (124)	32 (68)	56 (116)	1028 (2492)
8-10	88 (180)	68 (280)	88 (224)	460 (1340)	324 (852)	88 (248)	72 (168)	120 (200)	56 (180)	80 (148)	120 (236)	1564 (4056)
6-8	84 (264)	68 (348)	160 (384)	752 (2092)	564 (1416)	284 (532)	84 (252)	152 (352)	196 (376)	156 (304)	224 (460)	2724 (6780)
4-6	112 (376)	52 (400)	252 (636)	1456 (3548)	860 (2276)	284 (816)	272 (524)	288 (640)	212 (588)	260 (564)	280 (740)	4328 (11108)
2-4	40 (416)	56 (456)	288 (924)	2580 (6128)	1772 (4048)	556 (1372)	380 (904)	304 (944)	352 (940)	324 (888)	232 (972)	6884 (17992)
0.5-2	4 (420)	4 (460)	244 (1168)	2596 (8724)	2756 (6804)	652 (2024)	304 (1208)	208 (1152)	204 (1144)	208 (1096)	64 (1036)	7316 (25308)

1. Hours of Calm 8,788

2. Hours of occurrence of waves equalling or exceeding the indicated height are shown in parenthesis.

3. Wave heights were obtained by hindcasts from United States Weather Bureau Synoptic Charts.

fury adjacent to the "eye". Hurricanes move bodily along a path in a motion of translation at an average speed of approximately 12 miles per hour. The greatest damage caused by these tropical cyclones to shore areas is due to the immdation which usually accompanies them. This is especially true where there is a bay to the right of the point where the hurricane center moves inland. The rise of water in Narragansett Bay, Rhode Island, during the hurricane of September 1938, which moved inland west of this bay is an example of the devastating effect which such a condition can engender. The strong currents created by hurricanes is an important factor in the destruction caused by such storms. Only a few hurricanes which have passed through the New England area are known to have caused considerable destruction. Ivan Ray Tannehill, in his book "Hurricanes", mentions ten which occurred between 1635 and 1944. Recent hurricanes occurred on September 21, 1938, September 14-15, 1944, August 31, 1954 and September 11, 1954. These hurricanes caused extreme damage throughout New England including heavy coastal damage. However, along the shore between Pemberton Point and Cape Cod Canal the damage caused by the hurricanes was relatively minor in comparison with the northeast storms of April 20-22, 1940 and November 28-30, 1945. These storms are described briefly in the ensuing two paragraphs.

6. Northeast Storm of April 20-22, 1940. - The northern coast of New England was lashed by a northeast gale, accompanied by the highest tides since 1851, on April 20-22, 1940. The storm center moved slowly along the coast from a point in eastern Kentucky on the 20th, to a point north of Portland, Maine on the 22nd. The storm reached Boston, Massachusetts at about 4:00 P.M. on the 20th and lasted until about 11:00 P.M. on the 21st. The storm, coming at the time of spring tides, built up the normally high tides to extreme tides which continued through the 22nd. Extreme tide recorded at Commonwealth Pier in Boston was 13.8 feet above mean low water. Heavy surf pounded the coast during the gale and spray was reported to have dashed over the 110-foot tower at Minot's Light off Scituate and to have carried 25 feet above the 105-foot cliff on Deer Island in Boston Harbor. During the period of 31 hours, there was a wind velocity of 30 or more miles per hour at the East Boston Airport. The extreme instantaneous velocity recorded was 49 miles per hour. Before and after that of gale force, the wind was from the north, but during the gale the wind was from northeast. Damage occurred throughout the study area with principal coastal damage consisting of erosion of beaches and cliffs; destruction of sea walls and bulkheads; undermining of highways and buildings, several of which were demolished; and, the flooding of low lands, buildings and roads.

7. Northeast Storm of November 28-30, 1945. - This storm was the last of three severe storms attacking New England during the ten-day period of November 20-30. The first two storms, occurring on November 20 and 22, affected principally the states of New Hampshire and Maine. Damage within the study area was negligible. The storm damaging the study area was a three-day northeast storm occurring on November 28 to 30 inclusive, with high winds continuing through December 1. Its greatest intensity

Table C-2. Hours of Wave Occurrence During 3-Year Period 1948 - 1950

Range of Wave Height (feet)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	TOTAL
25-30		4 (4)	12 (12)	28 (28)	12 (12)		4 (4)					60 (60)
20-25		12 (16)	20 (32)	84 (112)	24 (36)	4 (4)	4 (8)					148 (208)
18-20		8 (24)	16 (48)	24 (136)	28 (64)	4 (8)	4 (12)			12 (12)	12 (12)	108 (316)
16-18	8 (8)	16 (40)	12 (60)	112 (248)	68 (132)	16 (24)	12 (24)			8 (20)	4 (16)	256 (572)
14-16	12 (20)	20 (60)	24 (84)	132 (380)	96 (228)	20 (44)	16 (40)	8 (8)	12 (12)	8 (28)	20 (36)	368 (940)
12-14	16 (36)	16 (76)	28 (112)	220 (600)	112 (340)	32 (76)	24 (64)	8 (16)	36 (48)	8 (36)	24 (60)	524 (1464)
10-12	56 (92)	136 (212)	24 (136)	280 (880)	188 (528)	84 (160)	32 (96)	64 (80)	76 (124)	32 (68)	56 (116)	1028 (2492)
8-10	88 (180)	68 (280)	88 (224)	460 (1340)	324 (852)	88 (248)	72 (168)	120 (200)	56 (180)	80 (148)	120 (236)	1564 (4056)
6-8	84 (264)	68 (348)	160 (384)	752 (2092)	564 (1416)	284 (532)	84 (252)	152 (352)	196 (376)	156 (304)	224 (460)	2724 (6780)
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20-25		12 (16)	20 (32)	84 (112)	24 (36)	4 (4)	4 (8)					148 (208)
18-20		8 (24)	16 (48)	24 (136)	28 (64)	4 (8)	4 (12)			12 (12)	12 (12)	108 (316)
16-18	8 (8)	16 (40)	12 (60)	112 (248)	68 (132)	16 (24)	12 (24)			8 (20)	4 (16)	256 (572)
14-16	12 (20)	20 (60)	24 (84)	132 (380)	96 (228)	20 (44)	16 (40)	8 (8)	12 (12)	8 (28)	20 (36)	368 (940)
12-14	16 (36)	16 (76)	28 (112)	220 (600)	112 (340)	32 (76)	24 (64)	8 (16)	36 (48)	8 (36)	24 (60)	524 (1464)
10-12	56 (92)	136 (212)	24 (136)	280 (880)	188 (528)	84 (160)	32 (96)	64 (80)	76 (124)	32 (68)	56 (116)	1028 (2492)
8-10	88 (180)	68 (280)	88 (224)	460 (1340)	324 (852)	88 (248)	72 (168)	120 (200)	56 (180)	80 (148)	120 (236)	1564 (4056)
6-8	84 (264)	68 (348)	160 (384)	752 (2092)	564 (1416)	284 (532)	84 (252)	152 (352)	196 (376)	156 (304)	224 (460)	2724 (6780)
4-6	112 (376)	52 (400)	252 (636)	1456 (3548)	860 (2276)	284 (816)	272 (524)	288 (640)	212 (588)	260 (564)	280 (740)	4328 (11108)
2-4	40 (416)	56 (456)	288 (924)	2580 (6128)	1772 (4048)	556 (1372)	380 (904)	304 (944)	352 (940)	324 (888)	232 (972)	6884 (17992)
0.5-2	4 (420)	4 (460)	244 (1168)	2596 (8724)	2756 (6804)	652 (2024)	304 (1208)	208 (1152)	204 (1144)	208 (1096)	64 (1036)	7316 (25308)

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Table C-2. Hours of Wave Occurrence During 3-Year Period 1948 - 1950

Range of Wave Height (feet)	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	TOTAL
25-30		4 (4)	12 (12)	28 (28)	12 (12)		4 (4)					60 (60)
20-25		12 (16)	20 (32)	84 (112)	24 (36)	4 (4)	4 (8)					148 (208)
18-20		8 (24)	16 (48)	24 (136)	28 (64)	4 (8)	4 (12)			12 (12)	12 (12)	108 (316)
16-18	8 (8)	16 (40)	12 (60)	112 (248)	68 (132)	16 (24)	12 (24)			8 (20)	4 (16)	256 (572)
14-16	12 (20)	20 (60)	24 (84)	132 (380)	96 (228)	20 (44)	16 (40)	8 (8)	12 (12)	8 (28)	20 (36)	368 (940)
12-14	16 (36)	16 (76)	28 (112)	220 (600)	112 (340)	32 (76)	24 (64)	8 (16)	36 (48)	8 (36)	24 (60)	524 (1464)
10-12	56 (92)	136 (212)	24 (136)	280 (880)	188 (528)	84 (160)	32 (96)	64 (80)	76 (124)	32 (68)	56 (116)	1028 (2492)
8-10	88 (180)	68 (280)	88 (224)	460 (1340)	324 (852)	88 (248)	72 (168)	120 (200)	56 (180)	80 (148)	120 (236)	1564 (4056)
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- c. At North Scituate, wave action battered down the sea wall at Minot Beach for a length of about 35 feet. Heavy seas flowed through this breach ripping up 400 feet of highway pavement and flooded the entire area. One cottage was destroyed and about 25 severely damaged. Utility and water lines were damaged.
- d. At North Scituate, minor damage occurred to 3 cottages and about 50 feet of the south end of the sea wall was destroyed. At Hatherly Beach, storm waves tossed riprap onto lawns and caused damage to several cottages. At Scituate Cliffs, road between First and Second Cliffs was buried under 2 feet of sand and stones. At Peggotty Beach, one cottage suffered moderate damage. The face of Fourth Cliff was badly eroded.
- e. Marshfield - Humarock Beach sea walls were overtopped by waves which caused deposition of sand and stones on lawns and damaged the fronts of several cottages. Two cottages were washed off of their foundations. At Fieldston, erosion occurred to the dune adjacent to the north end of the State sea wall causing an area 100 feet by 100 feet by 5 feet to be eroded from behind the sea wall. At Green Harbor, bulkheads (wooden and concrete) were destroyed, dunes and fill were cut back 8 to 10 feet; cottages were undermined and porches destroyed. Near the center of the beach, heavy stone masonry sea walls were demolished and the fill behind them was lost. Twenty-five cottages were severely damaged including damage to utilities and water lines.
- f. At Duxbury Beach, wave action caused apparent erosion of beach material to depth of 2 feet around foundations of cottages. All cottages suffered some damage from high water that left debris and stone strewn over the area beyond the backshore of the beach.
- b. At Plymouth Harbor, near the State Pier, about 60 feet of sidewalk was undermined and about 15 feet of embankment washed out. In Warren Cove, about 800 feet of sea wall along the base of Plymouth Beach and fronting Town Beach was destroyed. At Town Beach, groins were damaged; the concrete ramp to the bathhouse was destroyed; the steps, porch and skirting of the bathhouse was damaged; an area about 200 feet by 300 feet in the parking lot was washed out to a depth of about 3 feet. Route 3 to Cape Cod was incapacitated for three days by inundation and debris; and Eel River was filled by sand and debris. At Manomet Point, the bluff in vicinity of the Coast Guard Station was eroded about 5 feet. At White Horse Beach, three cottages were undermined and on the north side of the inlet the dune was cut back about 10 feet and fifteen cottages were damaged.

APPENDIX D

SHORE LINE AND OFFSHORE CHANGES

1. Basic Data. - Maps showing the position of the mean high water line at various portions of the shore for the years 1847, 1856-1858, 1893-1894, 1909, 1924, 1944, and the position of the 6-, 12-, 18-, 24- and 30-foot depth contours for the years 1846-1848, 1892-1893, 1924 and 1944 were furnished by Beach Erosion Board for use in this study. Shore line data for 1946 and 1956, and offshore data for 1946 are obtained from surveys made by this office. 1939 data in the vicinity of North River are from a survey made by the Boston District, Corps of Engineers. Small error may be expected in the position of the 1956 shore line due to the method which it was necessary to use to match this survey with previous data. The shore line and off shore data are shown on Plates 10-17.

2. Nantasket Beach. - This area consists of about 3-1/2 miles of sandy beach from Point Allerton to Atlantic Hill in Hull. The high water shore line changes have been small, consisting of less than 50 feet and no where exceeding 100 feet during the period of record. Both accretion and erosion have occurred with small amount of accretion dominating from 1847 to 1944. Along the southerly portion of the beach erosion occurred between 1847 and 1893 resulting in a horizontal landward movement of the mean high water line from 20 to 80 feet. Between 1893 and 1944 the beach prograded and mean high water line moved seaward to approximately the position it occupied in 1847 except at Point Allerton where it is about 75 feet landward of the 1847 position. The 1956 survey indicated additional accretion at Point Allerton and general erosion along the northerly half of Nantasket Beach. Along the southerly half seaward movement of the shore was indicated, except adjacent to Atlantic Hill, with the maximum amount of about 50 feet occurring near the center of the reach. The 1946 mean high water shore line covers only the southerly portion of the beach and is generally about 40 feet seaward of that of 1847 with the exception of the shore line at the Atlantic Hill end, where it is about 80 feet seaward. A small portion at the center of Nantasket Beach has experienced continuous accretion from 1847 to 1944, a total of about 80 feet. The northerly portion of the beach has been experiencing both accretion and erosion with net erosion at Point Allerton of about 50 feet. From 1847 and 1893 Point Allerton eroded 50 to 100 feet and from 1893 to 1944 it grew seaward about 50 feet by accumulation of a gravel and cobble bar.

3. The movement of the mean low water line is shown only for two years, 1847 and 1893, for the entire length of Nantasket Beach. During this period erosion was experienced along the entire length of beach, with the exception of one mile of shore at the southerly end. The horizontal movement of the mean low water line was generally 180 feet landward, varying between 150 and 300 feet. At Point Allerton the low water line eroded about 500 feet at one place. At the

southerly one mile of the beach both erosion and accretion occurred with accretion slightly dominating between 1847 and 1893, while about balancing between 1847 and 1946.

4. The changes of the 6-foot depth contour between 1847 and 1893 have been accretion along the northerly part of the beach and erosion along the southerly part. In the northerly area the 6-foot depth contour moved seaward for distances up to 200 feet and in the southerly area moved landward up to 100 feet. Between 1893 and 1944 various points of the 6-foot contour moved landward and others moved seaward along the northern part of the area, with the areas of progression about equalling the areas of retrogression. In the southern part of the area erosion moved the 6-foot depth contour landward for distances ranging up to 100 feet. The net result between 1847 and 1944 for the entire beach has been accretion in the northerly part of the area and erosion in the southerly part.

5. The changes of the 12-foot depth contour between 1847 and 1893 had similar net effects as the 6-foot contour. The northerly half of the beach experienced accretion in general with seaward movement of the contour varying up to 200 feet. However, there were areas in which the contour remained stabilized or moved landward. The southerly half of the 12-foot contour experienced varied movements indicating both erosion and accretion during the period, erosion amounting from 100 to 140 feet landward in places and accretion appearing to be a local result in general. Between 1893 and 1944 the 12-foot contour of the southerly one mile of the beach eroded for distances varying up to 50 feet while the rest moved seaward for distances varying up to 180 feet. The net effect between 1847 and 1944 has been accretion in the northerly part of the area and varying amounts of erosion and accretion in the southerly part of the area. The movement of the depth contours in the northerly portion have been approximately twice that of the contours in the southerly portion.

6. The changes in the 18-foot depth contour do not show evidence of any continuous process of erosion or accretion in specific areas, but show that processes reverse themselves at different periods. Between 1847 and 1893 erosion dominated the area northerly of the southerly one mile of the beach, with the 18-foot depth contour moving distances varying up to 150 feet seaward in accretion areas. Accretion dominated the southerly one mile, with movement of the contour between 1847 and 1893 averaging 200 to 300 feet seaward. At the southerly end of Nantasket Beach the 1893 contour indicates a shoal about 200 feet seaward of the main depth contour. Between 1893 and 1944, the processes of erosion and accretion were reversed in many areas. The net effect for the northerly portion of the area was accretion with the movements varying up to 250 feet and averaging 150 feet. The 1944 contour shows a number of new shoal areas seaward of the main depth contour, the shoals being 300 to 1500 feet seaward of the contour.

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12. The 18-foot depth contour exhibits all accretion from 1847 to 1893. At the center of the area, where the shoal finger was extending, the contour moved about 350 feet seaward with no change at the points $1/4$ of the distance from each end. At Gun Rock there was up to 250 feet of accretion which extended westward. At Green Hill accretion amounted to about 130 feet.

13. The 24- and 30-foot contours exhibited accretion on the Gun Rock end and erosion at the Green Hill end. The accretion at Gun Rock at the 24-foot depth was about 150 feet, while for the 30-foot depth it was about 150 feet. The erosion at the Green Hill end and at the center at the 24-foot depth was about 450 feet and 350 feet in two peaks. The erosion at the 30-foot depth was up to about 480 feet.

14. In summation, the shore line and offshore changes at the area from Gun Rock to Green Hill, for the period 1847 to 1893, exhibit both erosion and shoaling. In the offshore shoaling is predominant landward of the 24-foot depth and erosion is predominant seaward thereof.

15. Green Hill to Strawberry Point. - This area consists of about 4 miles of rocky, irregular shore and includes Little Harbor and Cohasset Harbor. Of the two surveys available, that of 1893 appears to have been more detailed delineating shoals, submarine canyons and other details not included in the survey of 1847. Therefore, many of the large changes indicated may be lack of detail in the 1847 survey. It is also of note that flat offshore slopes and extensive shoal areas are shown in the vicinity of Green Hill and Cohasset Harbor and large change in the position of the contours may be changes of small volume, or may possibly be in part error in location which was within the tolerable limits of the surveys. The high water changes in this area consist of a series of alternating erosion and shoaling sections which for most of the length balance out. Except for the south and easterly shore of Cohasset Harbor the movement of the shore line does not exceed 200 feet. The surveys indicate that the shore line of the salt marshes on the south and east sides of Cohasset Harbor receded during the period from 1847 to 1893 up to 1000 and 1400 feet respectively. A few islands in the offshore exhibit similar movements in their shore line.

16. The offshore depth changes, as for the shore line, are irregular. The 6-foot depth contour moved landward generally between 100 and 900 feet, except at short local areas where some accretion occurred. The 12-foot contour change followed generally the same pattern as the 6-foot, recession varied generally from about 100 to 400 feet with localized short sections of accretion except in the vicinity of Cohasset Harbor where shoal areas apparently formed. The 18-foot contour alternated between progression and recession at irregular intervals with a predominance of shoaling near Green Hill, opposite Little Harbor, and in the vicinity of Strawberry Point. The most significant

area of erosion was in the vicinity of Cohasset Harbor. Between Green Hill and a point north of Little Harbor the 24-foot contour has rather long alternate areas of recession then progression which about equalize each other. From thereon to Strawberry Point, the predominant movement is landward, the only large area in which the contour moved seaward is in the shoal area on the north side of Cohasset Harbor. The 30-foot depth contour follows the general pattern of the area, in which sections of the contour alternately progress and recede. East from Green Hill progression of the contour predominates with the only significant area of erosion occurring northeast of Cohasset Harbor. The net total effect as indicated by shore line and offshore changes between Green Hill and Strawberry Point appears to be that material is merely shifting within the area.

17. The Glades and Wellrock Beach. - Shore line change occurring at the Glades Beach is relatively unimportant since there is now an offshore breakwater, constructed parallel to the shore and backfilled along the southerly 85 percent of the area. However, the two surveys indicate slight accretion at the pocket beaches at each end and erosion between. At Wellrock there is a slight accretion at the southerly end and erosion throughout the remainder. Offshore contours show erosion at the 6- and 12-foot depths along the greater part of the Glades and accretion near the southerly end south to Bar Rocks. The 18-foot contour progressed seaward throughout, the average movement being about 400 feet. The 1847 survey did not extend through the Glades area, but the contours fronting the Wellrock area progressed seaward.

18. North Scituate Beach. - The area considered includes North Scituate Beach to the south end of the existing seawall, about 5000 feet in length. The northerly 1500 feet of shore line receded about 100 feet at the north to zero at the south between 1847 and 1894. The remainder progressed seaward slightly, a maximum of about 50 feet. The 6-foot contour receded slightly except along the southerly 1200 feet where it moved seaward averaging about 100 feet. The 12-, 18-, 24- and 30-foot contours moved seaward throughout from about 200 to 700 feet.

19. Mann Hill Beach to North End Cedar Point. - Surveys of 1847 and 1893. No data available for high water shore line in 1893. The 6-, 12- and 18-foot depth contours moved seaward from about 200 to 500 feet except for short segments near the center and south end of the reach where erosion occurred. The 24- and 30-foot contours moved seaward at a greater rate than the shallow contours, generally moving from about 400 feet to 1000 feet.

20. Cedar Point and Scituate Harbor. - Shore line data 1847, 1924, and 1944, offshore data 1847, 1893 and 1924. Cedar Point receded from 50 to 150 feet between 1847 and 1924 and progressed seaward from 0 to 100 feet between 1924 and 1944. In general the offshore contours in the northerly half of the reach moved seaward in

small amounts (in general about 50 feet) between 1847 and 1893 and receded (generally 150 to 300 feet) between 1893 and 1924. In the southerly half of the reach, the contours had rather mixed movements establishing no trend in direction.

21. First Cliff to Second Cliff. - Shore line data only for years of 1847, 1924 and 1944. The surveys indicate continued erosion on the north side of First Cliff totaling about 50 feet; on the south side erosion up to 50 feet between 1847 and 1924, and accretion up to about 25 feet between 1924 and 1944. Between the cliffs little change occurred consisting of slight erosion except along about 600 feet where accretion up to about 30 feet occurred. The south side of Second Cliff eroded to about 150 feet.

22. Third Cliff to North River Inlet. - Data between Second Cliff and North River are very limited. Data on a reach about 300 feet long located about 3500 feet south of Second Cliff indicate that between 1847 and 1857 the mean high water line retrograded from about 50 to 75 feet. During an intense storm in November 1898 the barrier beach between Third and Fourth Cliffs was breached creating a new inlet to North River and the old inlet, located about 16000 feet south of the present north end of Fourth Cliff, was closed. Available information indicates that the high water line at the south end of Third Cliff moved westward from 100 to 200 feet between 1858 and 1939. The barrier bar between Third and Fourth Cliffs remained essentially stable between 1857 and 1870, and as it was destroyed in 1898 did not show on the 1909 or 1939 surveys.

23. Fourth Cliff to Old North River Inlet (Humarock Beach). - Between 1857 and 1870 the high water line of the northerly 8000 feet of the reach moved seaward ranging from 50 feet at the north to zero at the south and between 1870 and 1939 the shore receded in amount ranging from 140 feet at the north to zero at the south. From the point about 8000 feet from the north end to the south end of the reach the shore eroded slightly between 1857 and 1870 then moved seaward up to 200 feet between 1870 and 1939. From the old inlet to a point 2500 feet south the shore receded up to 100 feet between 1857 and 1909.

24. Brant Rock. - Data are not available for the reach between Brant Rock and the reach discussed in the preceding paragraph. At Brant Rock the shore line receded between 1857 and 1909 in amounts ranging from about 125 feet at the northerly end to zero about 1700 feet south. From this point southward there was very little change, except for a pocket impoundment at the south end moving the high water line seaward about 100 feet.

25. Brant Rock to Duxbury Town Line. - Between 1857 and 1909 there was a continuous seaward movement averaging about 75 feet to Green Harbor. South from Green Harbor the surveys show a seaward movement of the shore line between 1857 and 1909 in amount of about

small amounts (in general about 50 feet) between 1847 and 1893 and receded (generally 150 to 300 feet) between 1893 and 1924. In the southerly half of the reach, the contours had rather mixed movements establishing no trend in direction.

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22. Third Cliff to North River Inlet. - Data between Second Cliff and North River are very limited. Data on a reach about 300 feet long located about 3500 feet south of Second Cliff indicate that between 1847 and 1857 the mean high water line retrograded from about 50 to 75 feet. During an intense storm in November 1898 the barrier beach between Third and Fourth Cliffs was breached creating a new inlet to North River and the old inlet, located about 16000 feet south of the present north end of Fourth Cliff, was closed. Available information indicates that the high water line at the south end of Third Cliff moved westward from 100 to 200 feet between 1858 and 1939. The barrier bar between Third and Fourth Cliffs remained essentially stable between 1857 and 1870, and as it was destroyed in 1898 did not show on the 1909 or 1939 surveys.

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Table E-2. Evidence of Predominant Direction of Littoral Drift

Shore Area	Indicated Predominant Direction of Drift	Evidence	Date	Authority
Pemberton	West	Build-up east of groins	Aug.27,1956 Aug.18,1952	Inspection Aerial Photo
Stony Beach	West	Build-up east of groins	Aug.27,1956 Aug.18,1952	Inspection Aerial Photo
Nantasket Beach	Slight South	Slight widening of beach at south	Aug.27,1956	Inspection
Straits Pond Beach	East	Beach eroding at west and noticeably wider at east end	Aug.28,1956	Inspection
Crescent Beach	West	Beach wider at center; no beach at east end	Aug.28,1956	Inspection
Cohasset Town Beach	South	Beach narrow and eroding at north; wider at south	Aug.28,1956	Inspection
North Scituate	Little predominance	Possible north drift	Aug.28,1956	Inspection
Green Harbor	North	Wider beach south of harbor jetties	Oct.22,1951	Aerial Photo
Plymouth Beach	North-west	Trailing of bars along spit and formation of spit	Oct.12,1952	Aerial Photo
White Horse Beach	North-west	Finer materials at north end	Apr. 3,1957	Inspection
Manomet Bluffs	South	Accretion on north side of groins	Apr. 3,1957	Inspection
Center Hill Point	South	Accretion on north side of groins	Apr. 4,1957	Inspection
Black Pond Area	South	Accretion on north side of groins	Apr. 4,1957	Inspection
Lookout Point	South	Accretion on north side of groins	Apr. 4,1957	Inspection
Sagamore Beach	South	Accretion on north side of groins	Apr.24,1957	Inspection
Scusset Beach	South	Accretion north of jetty	Apr.24,1957	Inspection

APPENDIX F

PROTECTIVE STRUCTURES

1. General: - A comprehensive listing and discussion of protective structures along the shore of the study area has been prepared. The information was obtained from field inspection, plans furnished by the Commonwealth of Massachusetts, permit drawings available in this office, annual reports of the Commonwealth, and aerial and ground photographs. The information follows in geographic order beginning at the north limit of the study area. The number in parentheses following the structure name is the assigned designation number locating that structure on Plates 2-9.

I - TOWN OF HULL

A. Pemberton Point

1. Sea Wall (1) - Existing length 2,400 feet. In 1923-1924 the Commonwealth of Massachusetts constructed 2,396 linear feet of new concrete wall which incorporated old walls that were in good condition. Details of the wall as built follow: top elevation of 18, 22 and 20 feet above MLW along the westerly, center and easterly portions; bottom elevations ranged from 6 to 10 feet above MLW; top width of 3 feet, 6 inches including a 12-inch lip; face batter of 0.2 foot per foot and back batter of 1-inch per foot. Stone spur jetties 20 feet long with a top width of 3 feet, a height of 4 feet and side slopes of 1 on 1 were placed at 50-foot intervals throughout the length of the wall. Riprap (1-a) consisting of $\frac{1}{2}$ to 4 ton granite blocks was placed along the westerly portion at a slope of 1 on 2.

(a) Repairs

- | | |
|-----------|---|
| 1931-1932 | Patching and concrete footing under and fronting 175 feet of wall. |
| 1937 | 140 feet of concrete footing added at westerly end extending 2 feet below toe of original wall. 1,000 tons stone placed along 520 feet of wall at westerly end. Stone placed on slope of 1 on 2 and extended to 4 feet above beach. |
| 1938 | Stone placed along wall extending 1937 work an additional 500 feet. |

1949 - Stone placed along 600 feet of wall.
Top width of 3 feet at elevation 15,
side slope 1 on 1.5, anchor stone
penetration of 2 feet.

2. Groins (2-5) - Groins (2,3) were constructed in 1938 as follows: length of 120 and 80 feet; landward top elevation of 13 and 11 feet above MLW; spacing of 300 feet; top width of 3 feet; bottom width of 18 feet; height of 5 feet; side slopes of 1 on 1.5; and the grade consistent with that of the beach. Groins(4,5) were constructed in 1949 as follows: length of 150 feet, top width of 8 feet, side slopes of 1 on 1, and cover stones penetrating into beach 2 feet.
3. Revetment (6) - Construction details not available. Wall appears to be about 700 feet long and composed of stone ranging in weight from chips to about 10 tons.
4. Condition - Seawall (1) in very bad condition, riprap (1a) in fair to good condition. Groins (2-5) in good condition and revetment (6) in good condition.

B. Stony Beach

1. Seawall (7) - Length about 2,600 feet. Wall consists of placed granite blocks with riprap toe protection, all above mean high water.
2. Revetment (10) - Length 2,375 feet. Adjoins structure (7) at the west end. The structure was constructed in 1934 of heavy dumped stone with top elevation of 22 feet above MLW, a top width of 4 feet and a slope of 1 on $1\frac{1}{4}$.
3. Seawall (11) - Existing length 1,800 feet. The concrete seawall constructed by Commonwealth of Massachusetts as follows: 1,431 feet in 1902, 300 feet in 1905, and 55 feet in 1931-1932. The wall ranges from 6 to 8 feet in height (or at about elevation 19.5) and has spur jetties 50 feet in length along the seaward side. The westerly end of the wall is protected by a placed stone revetment (11a) about 600 feet in length.

(a) Repairs

- 1905 - Repaired short section of undermined wall.
- 1925 - Scattered repairs.
- 1931-1932 - A concrete footing was placed under and in front of about 245 feet of wall.

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1. General. - A comprehensive listing and discussion of protective structures along the shore of the study area has been prepared. The information was obtained from field inspection, plans furnished by the Commonwealth of Massachusetts, permit drawings available in this office, annual reports of the Commonwealth, and aerial and ground photographs. The information follows in geographic order beginning at the north limit of the study area. The number in parentheses following the structure name is the assigned designation number locating that structure on Plates 2-9.

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(a) Repairs

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- 1938 Stone placed along wall extending 1937 work an additional 500 feet.

1949 - Stone placed along 600 feet of wall.
Top width of 3 feet at elevation 15,
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penetration of 2 feet.

2. Groins (2-5) - Groins (2,3) were constructed in 1938 as follows: length of 120 and 80 feet; landward top elevation of 13 and 11 feet above MLW; spacing of 300 feet; top width of 3 feet; bottom width of 18 feet; height of 5 feet; side slopes of 1 on 1.5; and the grade consistent with that of the beach. Groins (4,5) were constructed in 1949 as follows: length of 150 feet, top width of 8 feet, side slopes of 1 on 1, and cover stones penetrating into beach 2 feet.
3. Revetment (6) - Construction details not available. Wall appears to be about 700 feet long and composed of stone ranging in weight from chips to about 10 tons.
4. Condition - Seawall (1) in very bad condition, riprap (1a) in fair to good condition. Groins (2-5) in good condition and revetment (6) in good condition.

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(a) Repairs

- 1905 - Repaired short section of undermined wall.
- 1925 - Scattered repairs.
- 1931-1932 - A concrete footing was placed under and in front of about 245 feet of wall.

4. Seawall (12) - Existing length 1470 feet. This concrete seawall was constructed by the Commonwealth of Massachusetts in 1926-1927. The wall varied from 11 to 16 feet in height and in elevation from 19.4 to 21.6 feet above mean low water (west to east).

(a) Repairs

1931 - Minor repairs.

5. Groins (8,9) - Rough stone groins about 200 to 300 feet in length and spaced 500 feet apart. Details not available.
6. Present Condition - Structure (7) good, (8,9) fair, (10) good, (11) easterly 1200 feet very bad and westerly 600 feet together with (11a) very good, (12) fair to good.

C. Point Allerton

1. Seawall (13) - Existing length of 1202 feet. The masonry granite block wall was constructed by the Corps of Engineers during 1870-1874 to about elevation 22.6 feet. The wall is on a concrete foundation and was protected by about 1,005 feet of granite apron and 8 spur jetties. The apron was about 10 feet wide and 2 to 3 feet high. The jetties were 25-30 feet long, 6-8 feet wide and 2-3 feet high.
2. Condition - The structure is in good condition with toe now covered by a gravel and cobble bar.

D. Nantasket (town beach)

There are various private walls in low sections of dunes along this reach of about two miles. The walls are of concrete, stone masonry or concrete block. Photographs showing typical examples of these walls are on Plate 20.

E. Nantasket (MDC)

1. Present Protective Works - Present works consist of approximately 300 feet of stone revetment (14), 75 feet of concrete seawall (15), 500 feet stone revetment (16) and 4,800 feet of concrete seawall (17). The seawall was constructed between 1915 and 1938 to following dimensions: Top elevation 18.2 to 21.6 feet; toe elevation 7.6 to 9.2 feet; top width 1 to $1\frac{1}{2}$ feet. Several bastions project from wall at irregular intervals.

2. Prior Structures - Prior to 1900 heavy stone revetment protected the roadway. The existing seawalls were constructed seaward and the revetment covered by backfill.
3. Dates of Construction and Repair
 - 1915 - Construction of northerly portion of seawall.
 - 1916 - Construction of remainder of seawall.
 - 1937 - Area near water street backfilled.
 - 1940 - Reconstruction of about 175 feet of seawall.
 - 1943 - Wall extended.
 - 1945 - Reconstruction of about 160 feet of wall.
 - 1955 - Portions of seawall reinforced.
 - 1956 - Reconstruction of short section of deteriorated wall.

F. Straits Pond Beach (Gun Rock)

1. Seawall (18) - Total length about 800 feet. Construction details including date of construction not available. Stone masonry construction, about 8 inches thick and 5 to 6 feet above mean high water. Wall in good condition and apparently has received no recent damage.

G. Gun Rock Breakwater

1. Breakwater (19) - Rough stone breakwater constructed in 1916, to a length of about 200 feet, by the Commonwealth of Massachusetts. Original dimensions: top width of 15 feet at elevation 13.5 feet; side slopes 1 on 1.5 ocean side and 1 on 1 shore side.
2. Extensions and Repairs
 - 1917 - Extended to 375 feet in length with top width of 12 feet at elevation 15.0 feet. Side slopes 1 on 1, both sides.
 - 1923 - Breakwater raised to design height and reshaped. Shore end tied to higher ground.
 - 1928 - Breakwater raised and reshaped to 12-foot width at elevation 15.0 feet.
 - 1940-1941 - Seaward 165 feet of breakwater again raised to design height and extended 30 feet. About 2,600 tons of stone used.

H. Gun Rock

1. Seawall (20) - About 200 feet in length. Apparently constructed in 1913 at the time of structure (21). Wall in fair condition.

2. Prior Structures - Prior to 1900 heavy stone revetment protected the roadway. The existing seawalls were constructed seaward and the revetment covered by backfill.
3. Dates of Construction and Repair
 - 1915 - Construction of northerly portion of seawall.
 - 1916 - Construction of remainder of seawall.
 - 1937 - Area near water street backfilled.
 - 1940 - Reconstruction of about 175 feet of seawall.
 - 1943 - Wall extended.
 - 1945 - Reconstruction of about 160 feet of wall.
 - 1955 - Portions of seawall reinforced.
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 - 1928 - Breakwater raised and reshaped to 12-foot width at elevation 15.0 feet.
 - 1940-1941 - Seaward 165 feet of breakwater again raised to design height and extended 30 feet. About 2,600 tons of stone used.

H. Gun Rock

1. Seawall (20) - About 200 feet in length. Apparently constructed in 1913 at the time of structure (21). Wall in fair condition.

1956 - 175 feet of wall near center (immediately north of 22) undermined and overturned by March 1956 storms. Commonwealth replaced this section in 1957.

J. Green Hill

1. Seawall (24) - 1,400 feet of concrete wall constructed by Commonwealth of Massachusetts in 1913. The wall has a top elevation of 22 feet and has 15 spur jetties spaced along its length.
2. Repairs - In 1940 about 150 feet of wall 380 feet north of town line removed and replaced. Northerly 500 feet of wall in bad shape, remainder in fair to poor condition.

II - TOWN OF COHASSET

A. Green Hill

1. Seawall (25) - Stone masonry wall about 400 feet in length and constructed to about elevation 22 feet behind the town-owned beach. Construction details not available. Wall in fair condition.

B. Atlantic Avenue

1. Seawall (26) - Stone masonry wall about 400 feet in length to protect Atlantic Avenue. Construction details not available. Wall in good condition.

C. Cohasset Town Beach

1. Light Revetment (27) - Light stone revetment along backshore at seaward edge of parking area. Structure about 1,000 feet long, 2 feet high and is in good condition. Construction details not available.

III - TOWN OF SCITUATE

A. The Glades

1. Seawall - In 1902 the Commonwealth of Massachusetts constructed 1,450 feet of concrete seawall (28) between Minot Post Office and the rock outcrop to the north. The wall was about 8 feet high (elevation 20 feet), had a top width of 3 feet and a face batter of 2 inches per foot.

2. Repairs

- 1921-1922 - 253 feet of wall replaced by new wall with following dimensions: top width of 3 feet 1 inch at elevation 22 feet, a bottom width of 4 feet 10 inches, and a face batter of 2 inches per foot. 300 feet of footing installed south of new wall. Footing extended two feet in front of wall and had penetration of 3 feet. 7,500 cubic yards of gravel placed seaward of wall.
- 1923 - Some beach fill added and 20 tons of stone riprap placed in front of new wall.
- 1924 - 15.5 tons of riprap added.
- 1926 - 105 tons of riprap added.
- 1928 - Two sections of wall 200 feet and 100 feet in length were recapped.
- 1930 - Additional riprap added.
- 1933 - 128 feet of wall replaced to same dimension as preceding except used face batter of 3-3/16 inches per foot. 250 feet of wall recapped. 3,000 tons of riprap placed along 950 feet of wall with top width of 2 feet at elevation 20, and slope of 1 on 1.5.
- 1938 - Riprap repaired.
- 1939 - Riprap repaired.
- 1943 - One foot thick face placed over 560 feet of wall beginning about 400 feet north of southerly end of wall. New face extended about 1.5 feet below beach surface. Various areas of face patched.
- 1944 - New riprap placed beginning 700 feet north of southerly end as follows: top width of one foot at elevation 18 feet, slope 1 on 1.5, and anchor stone submerged 2 feet below beach surface. 320 feet of existing riprap rehandled.
- 1945 - 69 feet of concrete footing, beginning 269 feet north of southerly end, was constructed with a 2-foot penetration and extend 2 feet forward and behind existing wall. 2-5 ton stone placed along 111 feet of wall beginning 244 feet north of southerly end. Top at elevation 17.4 feet.
- 1946 - Recapped and refaced 40 feet of wall 740 feet from south end. Riprap replaced from 650 to 975 feet north of southerly end.
- 1948 - About 300 feet of wall north from point 640 feet north of southerly end was patched and riprap added.
- 1950-1951 - Additional patching.
- 1952 - A convex shaped stone breakwater (29) was constructed in the nearshore with the center 90 feet seaward of existing wall and ends meeting the wall 120 and 950 feet northerly of southerly end. Details as follows: top width of

15 feet at elevation 15 feet; seaward slope 1 on 2 and landward slope 1 on 1.25. Ordinary borrow backfill placed behind breakwater. Wave action has removed fines from fill leaving gravel and cobble beach between the breakwater and the wall.

1955 - About 200 feet of damaged wall replaced by Commonwealth of Massachusetts with new prefabricated concrete wall consisting of sections weighing 7 tons each.

B. Wellrock Beach

1. Seawall (30) - Stone masonry wall about 300 feet long at north end of beach. Wall in good condition. Construction details not available.

C. North Scituate Beach

1. Seawall (31) - About 2,200 feet of stone masonry between Wellrock Beach and Gannet Road except for sections of replacement concrete wall. Wall constructed by Commonwealth of Massachusetts. Portions of wall capped with concrete and portions refaced with concrete. Spur jetties are located throughout the length of the wall.

2. Construction and Repairs

- 1907 - 357 feet of stone masonry wall constructed at north end replacing timber bulkhead.
- 1920 - 343 feet of overturned masonry wall replaced with concrete. 21 concrete spur jetties, 15 feet long, constructed north from Gannet Road. 936 cubic yards backfill placed behind concrete wall. 185 feet of masonry wall repaired and recapped, concrete footing added, 7 spur jetties constructed and backfill added.
- 1922 - 1,015 feet of masonry wall at north end refaced with concrete. 40 spur jetties with following dimensions added: 15 feet long, 2-foot top width, 3-foot bottom width, shoreward end about 4 feet high with top at elevation 15. feet.
- 1940 - Two sections of wall at the north end, 203 and 77 feet long, were recapped.
- 1946 - Repointing of granite at south end.
- 1952 - 490 feet of wall at north end (fronting Cliff House) recapped to elevation 22. Bituminous walk along top of wall. Stone masonry retaining wall landward of walkway constructed about 6 feet high, 18 inches wide with face batter of 3 inches per foot.

2. Repairs

- 1921-1922 - 253 feet of wall replaced by new wall with following dimensions: top width of 3 feet 1 inch at elevation 22 feet, a bottom width of 4 feet 10 inches, and a face batter of 2 inches per foot. 300 feet of footing installed south of new wall. Footing extended two feet in front of wall and had penetration of 3 feet. 7,500 cubic yards of gravel placed seaward of wall.
- 1923 - Some beach fill added and 20 tons of stone riprap placed in front of new wall.
- 1924 - 15.5 tons of riprap added.
- 1926 - 105 tons of riprap added.
- 1928 - Two sections of wall 200 feet and 100 feet in length were recapped.
- 1930 - Additional riprap added.
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- 1938 - Riprap repaired.
- 1939 - Riprap repaired.
- 1943 - One foot thick face placed over 560 feet of wall beginning about 400 feet north of southerly end of wall. New face extended about 1.5 feet below beach surface. Various areas of face patched.
- 1944 - New riprap placed beginning 700 feet north of southerly end as follows: top width of one foot at elevation 18 feet, slope 1 on 1.5, and anchor stone submerged 2 feet below beach surface. 320 feet of existing riprap rehandled.
- 1945 - 69 feet of concrete footing, beginning 269 feet north of southerly end, was constructed with a 2-foot penetration and extend 2 feet forward and behind existing wall. 2-5 ton stone placed along 111 feet of wall beginning 244 feet north of southerly end. Top at elevation 17.4 feet.
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- 1948 - About 300 feet of wall north from point 640 feet north of southerly end was patched and riprap added.
- 1950-1951 - Additional patching.
- 1952 - A convex shaped stone breakwater (29) was constructed in the nearshore with the center 90 feet seaward of existing wall and ends meeting the wall 120 and 950 feet northerly of southerly end. Details as follows: top width of

15 feet at elevation 15 feet; seaward slope 1 on 2 and landward slope 1 on 1.25. Ordinary borrow backfill placed behind breakwater. Wave action has removed fines from fill leaving gravel and cobble beach between the breakwater and the wall.

1955 - About 200 feet of damaged wall replaced by Commonwealth of Massachusetts with new prefabricated concrete wall consisting of sections weighing 7 tons each.

B. Wellrock Beach

1. Seawall (30) - Stone masonry wall about 300 feet long at north end of beach. Wall in good condition. Construction details not available.

C. North Scituate Beach

1. Seawall (31) - About 2,200 feet of stone masonry between Wellrock Beach and Gannet Road except for sections of replacement concrete wall. Wall constructed by Commonwealth of Massachusetts. Portions of wall capped with concrete and portions refaced with concrete. Spur jetties are located throughout the length of the wall.

2. Construction and Repairs

- 1907 - 357 feet of stone masonry wall constructed at north end replacing timber bulkhead.
- 1920 - 343 feet of overturned masonry wall replaced with concrete. 21 concrete spur jetties, 15 feet long, constructed north from Gannet Road. 936 cubic yards backfill placed behind concrete wall. 185 feet of masonry wall repaired and recapped, concrete footing added, 7 spur jetties constructed and backfill added.
- 1922 - 1,015 feet of masonry wall at north end refaced with concrete. 40 spur jetties with following dimensions added: 15 feet long, 2-foot top width, 3-foot bottom width, shoreward end about 4 feet high with top at elevation 15. feet.
- 1940 - Two sections of wall at the north end, 203 and 77 feet long, were recapped.
- 1946 - Repointing of granite at south end.
- 1952 - 490 feet of wall at north end (fronting Cliff House) recapped to elevation 22. Bituminous walk along top of wall. Stone masonry retaining wall landward of walkway constructed about 6 feet high, 18 inches wide with face batter of 3 inches per foot.

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1954 - Work of 1952 extended 194 feet southward with elevation of seawall and stone masonry retaining wall 25.5 feet and 19.0 feet, respectively. A grouted stone apron was constructed in front of wall which was 30 inches deep with elevations 13, 11 and 9 feet at the wall, 15 feet seaward and 19 feet seaward, respectively. North of 1952 work 117 feet of new stone masonry retaining wall placed with top and bottom elevations of 25.5 and 19.0 feet. North from this work 237 feet of wall was recapped to elevation 23 and a 1-foot thick reinforced concrete face added.

3. Seawall (32) - About 2,700 feet of concrete seawall was constructed by the Commonwealth of Massachusetts south from Gannet Road. The wall incorporated existing private walls that were in good condition. Concrete spur jetties generally about 25 feet long and 100 to 150 feet apart are located along the face of the wall. Dates of construction and repairs follow:

1906-1907 - About 356 feet of concrete wall was constructed the north end of which joined structure (31).
1908 - About 650 feet of wall constructed adjoining work of 1906-1907.
1909 - Wall extended 279 feet.
1910 - 250 feet of wall underpinned and 120 feet of destroyed wall replaced. 5 spur jetties, each 25 feet long, were constructed 100 to 150 feet apart.
1916 - Additional 368 feet of wall and 3 spur jetties were constructed.
1923-1924 - 14 additional spur jetties constructed.
1927, 1929, 1930, 1931 - Random repairs made.
1931 - 8 concrete spur jetties constructed and about 600 feet of seawall added. Wall included access opening to the beach.
1933 - Repair of 100 feet of undermined wall and of a jetty.
1940 - Recapping of three sections of wall totaling 182 feet.
1946-1949 - Repair of wall and placement of 700 feet of riprap to following dimensions: top width of 3 feet at elevation 16 feet, anchor stone penetration of 2 feet, core of stone chips.

D. Shore Acres - Sand Hills

1. Revetment (33) - About 700 feet of heavy stone revetment with core of chips, is located north of north end

of seawall (34). About 800 tons of stone was placed in 1932 and in 1933 about 4,200 tons of heavy stone and 800 tons of stone chips were placed. No records are available on subsequent maintenance. Present condition good.

2. Seawall (34)¹ - About 5,500 feet of concrete seawall extends south from structure (33). Some length of privately constructed and county wall was incorporated into existing wall. Available information regarding construction and repair follows in chronological order.

- 1883 - A brush and stone bulkhead was constructed by the Corps of Engineers at south end of this reach. This was later replaced by concrete seawall.
- 1900 - Concrete seawall extending 998 feet from south end of existing wall constructed by the Commonwealth of Massachusetts. Top elevation 8 feet above MHW.
- 1922 - 250 feet of concrete wall with return and 5 spur jetties 15 feet long were constructed in Sand Hills.
- 1924 - About 1,000 feet of wall repaired in Sand Hills.
- 1931 - Two sections of wall 312 feet and 378 feet long constructed on the seaward side and harbor sides, respectively, of the neck. New cap, face and footing added to about 120 feet of wall. (Sand Hills)
- 1933-1934 - About 930 feet of wall at Shore Acres was constructed and 1,100 tons of riprap placed at its toe.
- 1933-1935 - About 2,750 feet of concrete seawall constructed and an apron of about 3,300 tons of heavy stone was placed between Shore Acres and Sand Hills.
- 1934 - Repair of seawalls and 148 feet of footing placed under wall in Sand Hills.
- 1951 - Riprap added.
- 1953 - A portion of wall repaired by recapping with a 3-foot wide cap, adding a 1-foot thick face and installing a concrete footing extending 3 feet seaward of the wall, 10-foot long fir sheeting was placed at seaward edge of footing about 250 feet of riprap reset and grouted.
- 1955 - 490 feet of old wall replaced with new concrete structure. Wall built with top width of 2.5 feet at elevation 21.5 feet, 12 inch lip, face batter of 2 inches per foot and back batter of 2.5 inches per foot. A footing two feet deep

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- 1900 - Concrete seawall extending 998 feet from south end of existing wall constructed by the Commonwealth of Massachusetts. Top elevation 8 feet above MHW.
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- 1931 - Two sections of wall 312 feet and 378 feet long constructed on the seaward side and harbor sides, respectively, of the neck. New cap, face and footing added to about 120 feet of wall. (Sand Hills)
- 1933-1934 - About 930 feet of wall at Shore Acres was constructed and 1,100 tons of riprap placed at its toe.
- 1933-1935 - About 2,750 feet of concrete seawall constructed and an apron of about 3,300 tons of heavy stone was placed between Shore Acres and Sand Hills.
- 1934 - Repair of seawalls and 148 feet of footing placed under wall in Sand Hills.
- 1951 - Riprap added.
- 1953 - A portion of wall repaired by recapping with a 3-foot wide cap, adding a 1-foot thick face and installing a concrete footing extending 3 feet seaward of the wall, 10-foot long fir sheeting was placed at seaward edge of footing about 250 feet of riprap reset and grouted.
- 1955 - 490 feet of old wall replaced with new concrete structure. Wall built with top width of 2.5 feet at elevation 21.5 feet, 12 inch lip, face batter of 2 inches per foot and back batter of 2.5 inches per foot. A footing two feet deep

1931 - Shore end of structure repaired.
1932 - 250 tons of stone toe protection added.

2. Revetment (39) - Rough stone revetment about 400 feet in length extends southerly from breakwater (38).
3. Revetment (40) - Smooth faced stone revetment extending about 600 feet south from structure (39). The structure was constructed in 1949 by the Commonwealth of Massachusetts and consists of a stone mound whose top is about elevation 22. The structure was back-filled with ordinary borrow. Structure in good condition except for about 6 to 8 places where toe stone has been moved by storm action.

G. First to Second Cliffs

1. Seawall (41) - Concrete seawall with six inch lip extends along about 1,250 feet of shore between the two cliffs. The wall is in fair condition with some deterioration of the face and lip noted at various points.

(a) Repairs

- 1907 - About 700 feet of wall constructed southerly from south end of 1st cliff and riprap placed at northerly end.
- 1915 - About 545 feet of additional wall constructed southerly from 1907 portion. Riprap placed along shore for 200 feet south of the wall.
- 1917 - 400 tons of riprap placed along the southerly portion of wall.
- 1920 - Repairs to wall.
- 1923 - Riprap placed along 300 feet of northerly portion of wall.

H. Second Cliff

1. Revetment (42) - About 1,600 feet of smooth face revetment with top elevation 20 feet, structure in good condition.

(a) Repairs

- 1932 - About 2,000 tons of riprap placed along southeasterly shore.
- 1951 - Rubble stone mound placed along northerly end of cliff. Loam placed on slope above structure and seeded.
- 1954 - Revetment extended southward.
- 1956 - Revetment placed along about 200 feet near center of cliff. Southerly portion widened.

2. Revetment (43) - Cobbles and boulders form revetment along about 600 feet of shore at south end of cliff and north end of Peggotty Beach

I. Third Cliff

1. Revetment (44) - Dumped stone revetment at toe of bluff along about 4,000 feet of shore. Revetment in fair to good condition but furnishes only partial protection due to steepness of bluff face.

(a) Repairs

- 1906-1907 - About 2,305 tons of stone placed along 385 feet of shore at southerly end in vicinity of Rivermoor.
 - 1908 - 1,038 tons of stone along 221 feet of shore north of the 1906-1907 work.
 - 1916 - Repair of southerly portion.
 - 1921 - About 3,700 tons of stone placed at south end.
 - 1922-1924 - Stone placed along about 1,450 feet of shore at northerly end.
 - 1923-1924 - About 8,000 tons placed along 1,400 feet of shore near center of bluff.
 - 1928 - About 128 tons added extending structure about 100 feet at northerly end.
 - 1931 - In various areas stone rehandled and about 2,000 tons of stone added.
 - 1933 - About 1,500 tons of stone placed.
 - 1954 - Various areas repaired.
2. Revetment (45) - This structure, constructed by the Commonwealth of Massachusetts in 1955, consists of a stone mound adjoining structure (44) on the south. The extension is about 500 feet long with a top width of 5 feet at elevation 20 feet. Side slopes are 1 on 2 on seaward and landward sides. Structure backfilled. Condition good.

J. Fourth Cliff

1. Revetment (46) - Placed stone mound constructed by Commonwealth of Massachusetts in 1954. Structure about 650 feet long, top width of 5 feet at elevation 22 feet, side slopes 1 on $1\frac{1}{2}$ seaward and 1 on 1 landward, backfill sloped to bluff at 1 on 4 slope, toe at elevation 11 feet.

K. Humarock Beach

1. Seawall (47) - About 4,100 feet of concrete seawall with 6-inch lip and 80 spur jetties constructed by the Commonwealth of Massachusetts. Wall in generally good condition.

(a) Repairs

- 1921 - About 2,300 feet of wall, return walls at ends, three sets of concrete steps, 46 concrete spur jetties each 25 feet long and a concrete apron constructed.
- 1928 - General repairs to wall.
- 1931 - About 1,775 feet of new concrete wall constructed south from 1921 portion. 34 concrete spur jetties constructed along wall.

IV - TOWN OF MARSHFIELD

A. Fieldston

- 1. Seawall (48) - In 1931 about 4,716 feet of concrete wall was constructed by the Commonwealth of Massachusetts. The construction also included 82 concrete spur jetties, riprap along about 650 feet of the wall and an access ramp at Beach Avenue.

(a) Repairs

- 1932 - Wall backfilled and steps over wall placed at about every third street.
- 1933 - Concrete footing placed under north end return wall.
- 1939 - Reinforced concrete fence added to steps at Ninth Street.

B. Ocean Bluff

- 1. Seawall (49) - About 800 feet of concrete seawall adjoins structure (48) on the south. The structure appears to be in good condition. Available information on this wall follows:
 - 1931 - An existing revetment was modified by addition of concrete face and footing and a portion replaced by concrete wall.
 - 1933 - About 400 feet of concrete seawall, 115 feet reinforced concrete footing and 250 feet of capping and backing to existing masonry wall was constructed. 250 feet of wall backfilled.
 - 1952 - About 700 feet of wall repaired by addition of cap which raised top to elevation 23.5 feet. Wing walls 25 feet long added at each end. (Beach Avenue and Shepard Avenue)

(a) Repairs

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B. Ocean Bluff

1. Seawall (49) - About 800 feet of concrete seawall adjoins structure (48) on the south. The structure appears to be in good condition. Available information on this wall follows:

1931 - An existing revetment was modified by addition of concrete face and footing and a portion replaced by concrete wall.

1933 - About 400 feet of concrete seawall, 115 feet reinforced concrete footing and 250 feet of capping and backing to existing masonry wall was constructed. 250 feet of wall backfilled.

1952 - About 700 feet of wall repaired by addition of cap which raised top to elevation 23.5 feet. Wing walls 25 feet long added at each end. (Beach Avenue and Shepard Avenue)

1954 - Sandfill was placed between groin (54) and a point 550 feet southward. The fill was placed with a berm varying in width from 40 to 60 feet at elevation 15 feet and the toe at about mean low water.

1956 - Grouted stone apron (56) placed between groin (54) and a point about 600 feet southward. The structure slopes from elevation 12 feet at the seawall to elevation 10.5 feet at a point 15 feet seaward, then follows a slope of 1 on 3 to elevation 5 feet. The sand fill was placed on a 1 on 10 slope over the stone with the crest of the beach at the seawall at elevation 14 feet providing a beach width of 35 feet above high water.

D. Brant Rock (South of Brant Rock Jetty)

1. Seawall (57) - This is a continuation of seawall (53) extending about 700 feet south of Brant Rock jetty (52). The condition of the wall is fair to good.
2. Revetment (58) - This is a light weight stone revetment joining seawall (57) and extending about 1,200 feet southward. Revetment in good condition.
3. Seawall (59) - Concrete seawall joining revetment (58) and extending about 1,000 feet southward. Wall in good condition.
4. Revetment (60) - Rough stone revetment joining seawall (59) and extending about 1,200 feet around Green Harbor Point. Revetment in fair to good condition.

E. Green Harbor

The harbor is protected by two stone mound jetties (61, 62) constructed for navigation purposes by the Commonwealth of Massachusetts in 1898-1899. The north jetty (61) is about 750 feet long and the southerly jetty (62) is about 1,350 feet long. The jetties were constructed with their outer ends about 200 feet apart, top width of 5 feet at about elevation 11.5 feet, side slopes vary from 1 on 1 to 1 on 2. The structures appear in good condition. Available data on maintenance follows:

1900 - Backfill placed at land end of southerly jetty and the timber bulkhead at the landward end was extended about 350 feet to mean high water line. The top was constructed to elevation 15 feet.

- 1901 - Repairs made to landward end of southerly jetty.
- 1930-1931 - About 660 feet of timber fence constructed on southerly side of the south jetty.
- 1931 - Both jetties reconstructed and about 550 feet of timber fence constructed south of south jetty. 196 feet of concrete wall constructed at landward end of north jetty.
- 1933 - About 600 tons of stone riprap placed at landward end of north jetty.
- 1947-1948 - About 700 feet of south jetty reconstructed and jetty extended about 60 feet. New jetty constructed 5 feet wide at elevation 12 feet with side slopes of 1 on 1.5.
- 1949-1950 - Reconstruction of damaged sections of south jetty.

F. Harbor to Town Line

- 1. Seawall (63) - About 1,100 feet of concrete seawall is located northward from the town line. The wall appears in good condition.

(a) Repairs

- 1940 - About 20 feet of seawall providing for an entrance to the beach and stop planks was constructed.
- 1947 - Reconstruction and repair of existing seawall.

V - TOWN OF DUXBURY

A. Duxbury

- 1. Seawall (64) - Concrete seawall joining seawall (63) and extending about 750 feet. Wall was constructed by the Commonwealth of Massachusetts as follows: top width of 30 inches, including a 12-inch by 12-inch lip, at elevation 22 feet; bottom width of 5 feet, 4 inches at elevation 10.5 feet and a concrete footing underneath about 6 feet, 10 inches at elevation 9 feet; face and back batter of 2 inches per foot; a return wall at south end; and backfilled throughout. History of area follows:

- 1946 - Stone riprap placed.
- 1947 - Several sections of concrete wall constructed south of Duxbury Town Line.

- 1901 - Repairs made to landward end of southerly jetty.
- 1930-1931 - About 660 feet of timber fence constructed on southerly side of the south jetty.
- 1931 - Both jetties reconstructed and about 550 feet of timber fence constructed south of south jetty. 196 feet of concrete wall constructed at landward end of north jetty.
- 1933 - About 600 tons of stone riprap placed at landward end of north jetty.
- 1947-1948 - About 700 feet of south jetty reconstructed and jetty extended about 60 feet. New jetty constructed 5 feet wide at elevation 12 feet with side slopes of 1 on 1.5.
- 1949-1950 - Reconstruction of damaged sections of south jetty.

F. Harbor to Town Line

1. Seawall (63) - About 1,100 feet of concrete seawall is located northward from the town line. The wall appears in good condition.

(a) Repairs

- 1940 - About 20 feet of seawall providing for an entrance to the beach and stop planks was constructed.
- 1947 - Reconstruction and repair of existing seawall.

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- 1946 - Stone riprap placed.
- 1947 - Several sections of concrete wall constructed south of Duxbury Town Line.

- 1836-1839 - Repairs to existing wall and construction of stone fill timber crib wall.
\$2,500 expended.
- 1840-41 - Minor repairs.
- 1853 - Closed 2,400 linear feet of breach caused by 1851 storm, using triangular-shaped timber cribs filled with stone.
- 1854 - Additional repairs.
- 1866 - Replaced 1,300 feet of stone filled timber cribs.
- 1868 - 200 feet of stone filled timber cribs constructed.
- 1872 - Constructed 200 linear feet of brush bulkhead, added 613 tons of stone, 300 linear feet of brush jetties, 250 feet of stone jetties, and planted beach grass.
- 1873 - Constructed 23 brush and stone jetties (3,000 lin. ft.), 10 brush jetties (534 lin. ft.), and planted beach grass.
- 1874 - Constructed 3,100 lin. ft. of stone and brush groins 320 ft. of brush groins and 110 ft. timber cribs filled with brush and stones.
- 1875-1882 - Bulkhead (stone) on outer end extended, previously constructed works repaired annually.
- 1883 - Extended stone bulkhead 830 feet, repaired 640 feet of wall making it sand tight, constructed 730 feet timber and stone fence alongside dilapidated wall.
- 1886 - Extensive repairs to bulkhead at root of spit and cleaning out of Eel River.
- 1888 - Closure of 4 branches in northern portion by construction of 370 feet of timber plank bulkhead.
- 1892 - 1,300 feet of bulkhead repaired.
- 1899-1905 - A storm in November 1898 destroyed practically all protective works on Long Beach, lowered the general level of the spit, and blocked the entrance to Eel River. 11,843 linear feet of stone dike was constructed at a cost of \$72,434.18. In addition 536 linear feet of stone dike was constructed along Eel River to prevent its meandering through the beach.
- 1910-1911 - Stone dike extended 616 feet. (Total length 12,459 feet. Repair of 2,133 feet of existing dike.)
- 1912 - 1,300 feet of dike repaired.
- 1936 - 8,000 feet of dike repaired
- 1957 - Dike repairs.

B. Warren Cove - This is a cove formed by Plymouth (Long) Beach on the north and Rocky Point on the south. The shore in the cove is fronted by about 2,600 feet of concrete seawall (69) fronted by riprap or apron followed by 1,000 feet of rough stone revetment (70), and 1,150 feet of stone mound revetment (71) constructed by the Commonwealth in 1957. The northerly 1,000 feet of structure 69 is in excellent condition, the following 300 feet in good condition, the following 1,200 feet in fair condition and the southerly 100 feet is overturned or in very bad condition. Revetment (70) is in generally good condition but erosion occurs above the structure. Revetment (71) is recently completed. One stone groin (68) is located about 75 feet north of the bath house and is in very poor condition. One groin (69) was constructed in April 1957 about 240 feet south of the bathhouse at the south end of the Town Beach.

1. Construction and Repairs

- 1915-1917 - 945 feet of concrete seawall with spurs at about 50 foot intervals was constructed.
- 1933-1934 - 265 feet of concrete seawall and 5 spurs were constructed, 4,200 tons of riprap placed.
- September 1940 - 600 linear feet of riprap was placed south of the bathhouse. About 375 linear feet was placed along the seawall northward from a point about 300 feet north of the south end. This revetment had a top elevation about 15 feet and side slope of 1 on 1.5. About 225 feet of revetment was placed along the bluff south from a point about 350 feet south of the south end of the seawall. This revetment had a top elevation of 25 feet above MSL and side slopes of 1 on 1.5.
- December 1940 - About 680 feet of riprap was placed joining together the two sections placed in April 1940. The northerly 300 feet of the revetment was placed over the concrete wall and the southerly portion was placed behind the wall. The revetment was placed on a 1 on 1.5 slope to elevation 25 feet. Gravel backfill was placed behind the seawall along the northerly 300 feet and loam was placed along the slope above the top of the revetment.
- March 1946 - A stone groin about 200 feet long, landward end elevation 12 feet, outer end 6.3 feet, top width 3 feet and side slopes of 1 on 1.5 was constructed about 75 feet north of the bathhouse. This groin is now in very poor condition. Southward from the groin, 220 feet

- of stone riprap was placed along the seawall. The top of the riprap was elevation 12 feet and seaward slope was 1 on 1.5.
- December 1946 - (1) From south end of bathhouse straightened 164 feet of seawall to erect position and placed a concrete cap and face. Cap to elevation 19 ft. and face extended 18 inches below wall.
- (2) Constructed 43 feet of new wall from section (1) southward. New wall had top thickness of 3 ft. 6 inches, bottom thickness of 6 ft. 4-1/2 inches, top elevation 19 feet, face batter 1 in. per ft., back batter 2 inches per foot.
- (3) 27 feet of wall joining (2) straightened to erect position.
- (4) 30 feet of wall 190 feet southward from (3) straightened to erect position.
- (5) 179 feet of new wall constructed southward from (4) - Top elevation 20 feet, top width 2 ft. 6 in., bottom width 4 ft. 3 in., face and back batter 1-1/4 in. per ft.
- (6) 1,000 linear feet of stone revetment placed in front of concrete wall southward from south end of bathhouse. Top width of 2 feet at elevation 16 feet and seaward slope of 1 on 1.5.
- October 1954 - Approximately 325 feet of new concrete seawall constructed, extending seawall northerly from its terminus about 425 feet north of north end of bathhouse. Top elevation 20 ft., bottom elevation about 11 feet, top width 2 ft. 6 in., bottom width 5 feet 9-1/2 in., face and back batter 2-1/2 inches per foot. Stone apron placed along new wall with top elevation of 15 feet sloping seaward on a 1 on 8 slope to elevation 13 feet. Gravel backfill behind wall.
- October 1956 - Seawall extended 110 feet northward. New wall top elevation 20 ft., top width 2 ft. 6 in., bottom width 5 ft. 9-1/2 in., bottom elevation 11 feet, 6 in. lip, face and back batter 2-1/2 inches per foot. Gravel backfill placed behind wall raising area (to be used for parking) to elevation 19 feet. Stone apron placed in front of new wall, top elevation 15 feet sloping seaward to elevation 13 feet a distance of 15 feet from seawall. Stone size ranged from 1/2 ton to 3 tons.
- April 1957 - Stone groin 170 feet long constructed at south limit of Town Beach (240 feet south of bathhouse). Inner end of groin (at seawall) elevation 14 feet, outer end elevation 6 feet, top width 6 feet, side

B. Warren Cove - This is a cove formed by Plymouth (Long) Beach on the north and Rocky Point on the south. The shore in the cove is fronted by about 2,600 feet of concrete seawall (69) fronted by riprap or apron followed by 1,000 feet of rough stone revetment (70), and 1,150 feet of stone mound revetment (71) constructed by the Commonwealth in 1957. The northerly 1,000 feet of structure 69 is in excellent condition, the following 300 feet in good condition, the following 1,200 feet in fair condition and the southerly 100 feet is overturned or in very bad condition. Revetment (70) is in generally good condition but erosion occurs above the structure. Revetment (71) is recently completed. One stone groin (68) is located about 75 feet north of the bath house and is in very poor condition. One groin (69) was constructed in April 1957 about 240 feet south of the bathhouse at the south end of the Town Beach.

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- December 1940 - About 680 feet of riprap was placed joining together the two sections placed in April 1940. The northerly 300 feet of the revetment was placed over the concrete wall and the southerly portion was placed behind the wall. The revetment was placed on a 1 on 1.5 slope to elevation 25 feet. Gravel backfill was placed behind the seawall along the northerly 300 feet and loam was placed along the slope above the top of the revetment.
- March 1946 - A stone groin about 200 feet long, landward end elevation 12 feet, outer end 6.3 feet, top width 3 feet and side slopes of 1 on 1.5 was constructed about 75 feet north of the bathhouse. This groin is now in very poor condition. Southward from the groin, 220 feet

- of stone riprap was placed along the seawall. The top of the riprap was elevation 12 feet and seaward slope was 1 on 1.5.
- December 1946 - (1) From south end of bathhouse straightened 164 feet of seawall to erect position and placed a concrete cap and face. Cap to elevation 19 ft. and face extended 18 inches below wall.
- (2) Constructed 43 feet of new wall from section (1) southward. New wall had top thickness of 3 ft. 6 inches, bottom thickness of 6 ft. 4-1/2 inches, top elevation 19 feet, face batter 1 in. per ft., back batter 2 inches per foot.
- (3) 27 feet of wall joining (2) straightened to erect position.
- (4) 30 feet of wall 190 feet southward from (3) straightened to erect position.
- (5) 179 feet of new wall constructed southward from (4) - Top elevation 20 feet, top width 2 ft. 6 in., bottom width 4 ft. 3 in., face and back batter 1-1/4 in. per ft.
- (6) 1,000 linear feet of stone revetment placed in front of concrete wall southward from south end of bathhouse. Top width of 2 feet at elevation 16 feet and seaward slope of 1 on 1.5.
- October 1954 - Approximately 325 feet of new concrete seawall constructed, extending seawall northerly from its terminus about 425 feet north of north end of bathhouse. Top elevation 20 ft., bottom elevation about 11 feet, top width 2 ft. 6 in., bottom width 5 feet 9-1/2 in., face and back batter 2-1/2 inches per foot. Stone apron placed along new wall with top elevation of 15 feet sloping seaward on a 1 on 8 slope to elevation 13 feet. Gravel backfill behind wall.
- October 1956 - Seawall extended 110 feet northward. New wall top elevation 20 ft., top width 2 ft. 6 in., bottom width 5 ft. 9-1/2 in., bottom elevation 11 feet, 6 in. lip, face and back batter 2-1/2 inches per foot. Gravel backfill placed behind wall raising area (to be used for parking) to elevation 19 feet. Stone apron placed in front of new wall, top elevation 15 feet sloping seaward to elevation 13 feet a distance of 15 feet from seawall. Stone size ranged from 1/2 ton to 3 tons.
- April 1957 - Stone groin 170 feet long constructed at south limit of Town Beach (240 feet south of bathhouse). Inner end of groin (at seawall) elevation 14 feet, outer end elevation 6 feet, top width 6 feet, side

- of stone riprap was placed along the seawall. The top of the riprap was elevation 12 feet and seaward slope was 1 on 1.5.
- December 1946 - (1) From south end of bathhouse straightened 164 feet of seawall to erect position and placed a concrete cap and face. Cap to elevation 19 ft. and face extended 18 inches below wall.
- (2) Constructed 43 feet of new wall from section (1) southward. New wall had top thickness of 3 ft. 6 inches, bottom thickness of 6 ft. 4-1/2 inches, top elevation 19 feet, face batter 1 in. per ft., back batter 2 inches per foot.
- (3) 27 feet of wall joining (2) straightened to erect position.
- (4) 30 feet of wall 190 feet southward from (3) straightened to erect position.
- (5) 179 feet of new wall constructed southward from (4) - Top elevation 20 feet, top width 2 ft. 6 in., bottom width 4 ft. 3 in., face and back batter 1-1/4 in. per ft.
- (6) 1,000 linear feet of stone revetment placed in front of concrete wall southward from south end of bathhouse. Top width of 2 feet at elevation 16 feet and seaward slope of 1 on 1.5.
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APPENDIX G

COST OF IMPROVEMENTS

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2. Detailed Costs. - First costs are based on price levels of May 1957. An interest rate of 2-1/2 percent and amortization on the basis of 2-1/2 percent for 50-year life of project is used. Details of the plans are shown on Plate 19.

A. Crescent Beach

1. First Cost

Beach Fill, 200,000 cu. yds. sand	
@ \$1.20	\$240,000
Revetment, 2,100 tons stone @ \$5.00	10,500
Contingencies	<u>37,500</u>
Sub-total	\$288,000
Engineering and Design	<u>9,000</u>
Sub-total	\$297,000
Supervision and Administration	<u>23,000</u>
Total First Cost	\$320,000

2. Annual Charges

Interest	\$ 8,000
Amortization	3,300
Maintenance	
Sand Fill, 3,000 cu. yds. sand	
@ \$1.50	4,500
Revetment, 20 tons stone @ \$7.50	<u>100</u>
Total Annual Charges	\$ 15,900

B. The Glades (Breakwater plan)

1. First Cost

Stone Breakwater, 10,900 tons of stone @ \$5.00	\$ 54,500
Contingencies	<u>8,200</u>
Sub-total	\$ 62,700
Engineering and Design	<u>1,900</u>
Sub-total	\$ 64,600
Supervision and Administration	<u>5,200</u>
Total First Cost	\$ 70,000

2. Annual Charges

Interest	\$ 1,700
Amortization	700
Maintenance - 100 tons of stone @ \$6.00	<u>600</u>
Total Annual Charges	\$ 3,000

C. The Glades (Sand fill plan)

1. First Cost

Sand Fill, 60,000 cu. yds. @ \$1.25	\$ 75,000
Contingencies	<u>11,000</u>
Sub-total	\$ 86,000
Engineering and Design	<u>2,500</u>
Sub-total	\$ 88,500
Supervision and Administration	<u>7,500</u>
Total First Cost	\$ 96,000

2. Annual Charges

Interest	\$ 2,400
Amortization	1,000
Maintenance - Sand fill, 2,500 cu. yds. sand @ \$1.50	<u>3,700</u>
Total Annual Charges	\$ 7,100

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Total Annual Charges	\$ 3,000

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Interest	\$ 1,700
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2. Annual Charges

Interest	\$ 1,700
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Maintenance - 100 tons of stone @ \$6.00	<u>600</u>
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Interest	\$ 1,700
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Maintenance - 100 tons of stone @ \$6.00	<u>600</u>
Total Annual Charges	\$ 3,000

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Supervision and Administration	5,200
Total First Cost	\$ 70,000

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Total Annual Charges	\$ 3,000

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2. Annual Charges

Interest	\$ 2,400
Amortization	1,000
Maintenance - Sand fill, 2,500 cu. yds. sand @ \$1.50	3,700
Total Annual Charges	\$ 7,100

(b) Recreational Benefits. - The greatest problem affecting beach attendance at Brant Rock is the lack of parking facilities. According to local officials, there are facilities for the parking of about 200 cars in the center of the main street in the commercial zone, along the seawall at the north end of the beach, in the small parking area adjacent to the seawall at the south end of the beach, parallel to the street at south end of the beach and in a commercial parking lot near the south end of the beach. Assuming 4 to 5 persons per car, from 800 to 1,000 people may drive their cars to the beach. The present beach area provides for about 1,600 persons, allowing 75 square feet per person, which appears adequate for anticipated peak attendance. The beach enlarged to project dimensions would provide area for 2,700 additional persons, but it does not appear that such peak attendance may be anticipated with present parking facilities; therefore, no recreational benefit is evaluated. However, the users of the beach should derive greater pleasure and comfort from the improved beach.

(c) Summary of Benefits. -

Direct Damages Prevented	19,700
Recreational	<u>0</u>
Total	19,700

3. Plymouth Town Beach. -

(a) Direct Damages Prevented. - Plymouth Town Beach is also an area exposed to heavy sea during easterly storms. The beach has a town owned and operated bathhouse and parking facilities for about 300 to 400 cars. Since the proposed improvement will result in a benefit from elimination of the necessity of continuing reconstruction of various protective works of the type used in the past, the direct damages are considered to be an amount equal to the average annual amount spent on such works during the period of record. These costs which have been considered fully justified by the protection afforded town facilities and the State highway are adjusted to the 1956 price level and are as follows:



FIG. 7. MANN HILL BEACH, SCITUATE. September 18, 1956. South from near north end of shingle barrier.

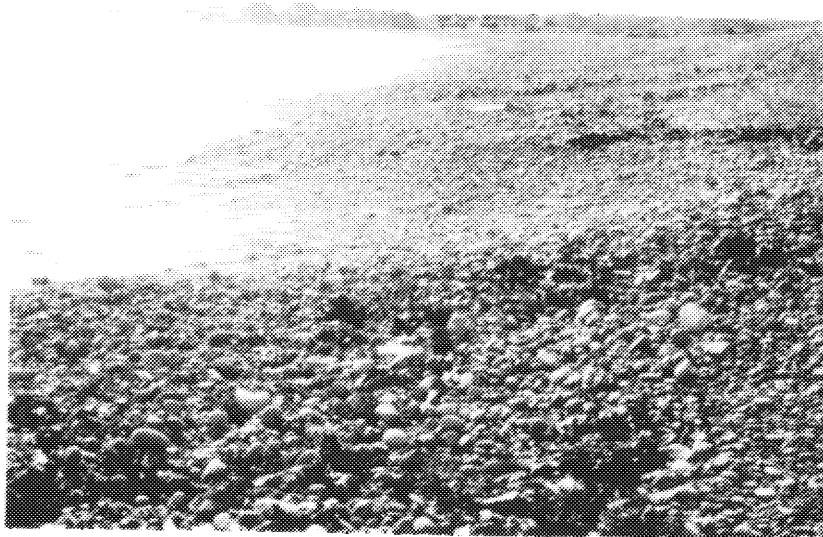


FIG. 8. MANN HILL BEACH, SCITUATE. September 18, 1956. South from about center of shingle barrier.



FIG. 9. SAND HILLS, SCITUATE. September 19, 1956. North along Sand Hills beach.



FIG. 7. MANN HILL BEACH, SCITUATE. September 18, 1956. South from near north end of shingle barrier.

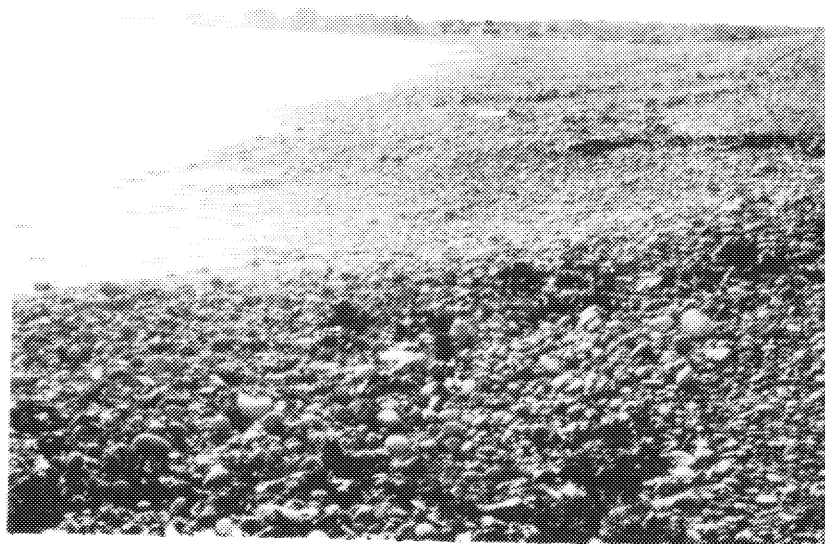


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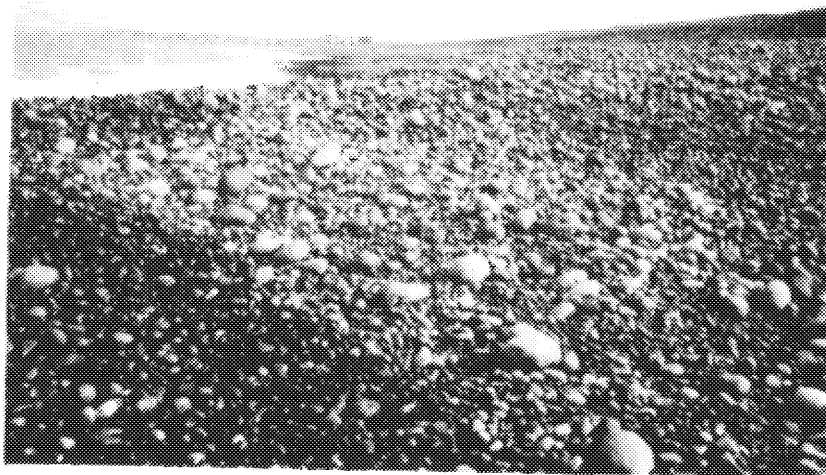


FIG. 7. MANN HILL BEACH, SCITUATE. September 18, 1956. South from near north end of shingle barrier.

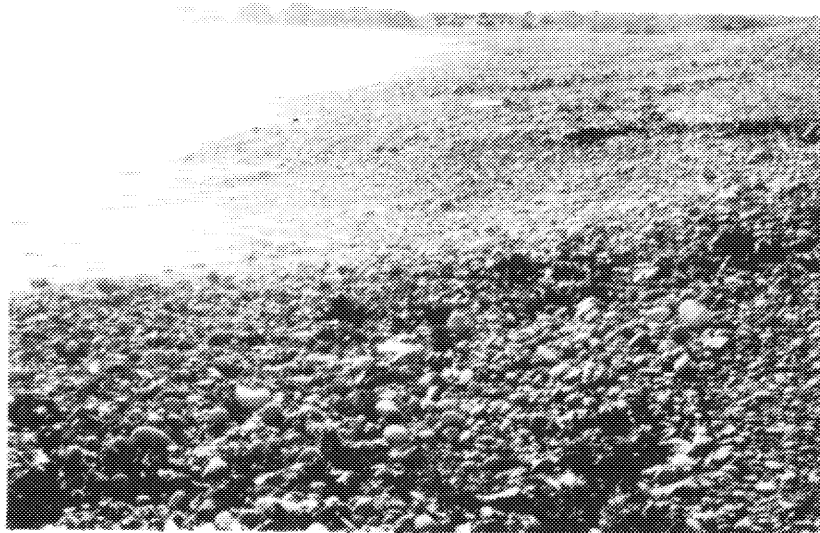


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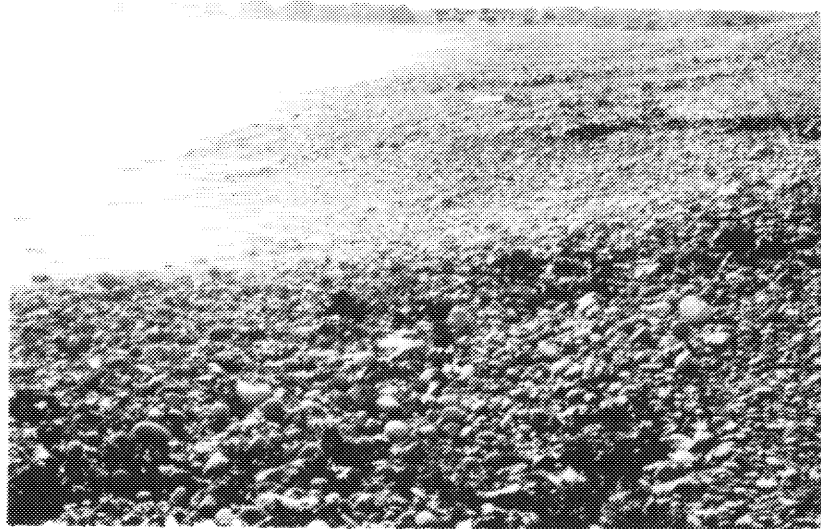


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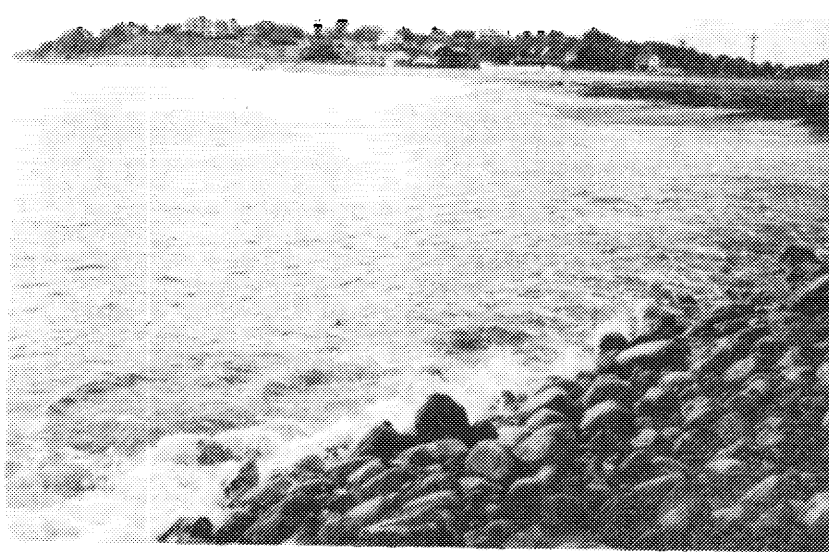


FIG.10. FIRST TO SECOND CLIFFS, SCITUATE. September 18, 1956. South toward Second Cliff from south end of First Cliff.



FIG.11. REXHAME, MARSHFIELD. September 18, 1956. South along Rexhame Beach.



FIG.12. BRANT ROCK, MARSHFIELD. September 18, 1956. North from about center of Brant Rock Beach.



FIG.10. FIRST TO SECOND CLIFFS, SCITUATE. September 18, 1956. South toward Second Cliff from south end of First Cliff.



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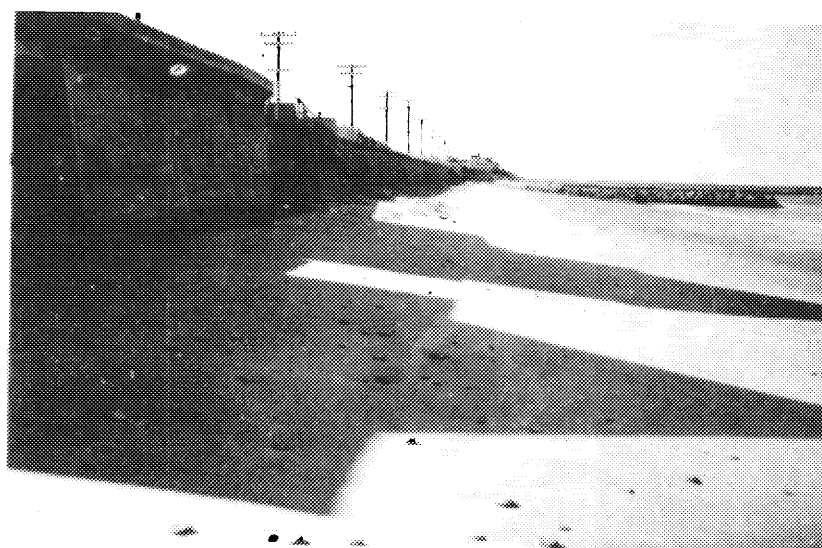


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FIG.10. FIRST TO SECOND CLIFFS, SCITUATE. September 18, 1956. South toward Second Cliff from south end of First Cliff.



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FIG.12. BRANT ROCK, MARSHFIELD. September 18, 1956. North from about center of Brant Rock Beach.



FIG.13. BRANT ROCK, MARSHFIELD. September 18, 1956. South from about center of beach.



FIG.14. GREEN HARBOR BEACH, MARSHFIELD. September 18, 1956. South from near west jetty at Green Harbor River.



FIG.15. DUXBURY BEACH, DUXBURY. September 18, 1956. South from a point north of Duxbury Beach bathhouse.



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FIG.15. DUXBURY BEACH, DUXBURY. September 18, 1956. South from a point north of Duxbury Beach bathhouse.

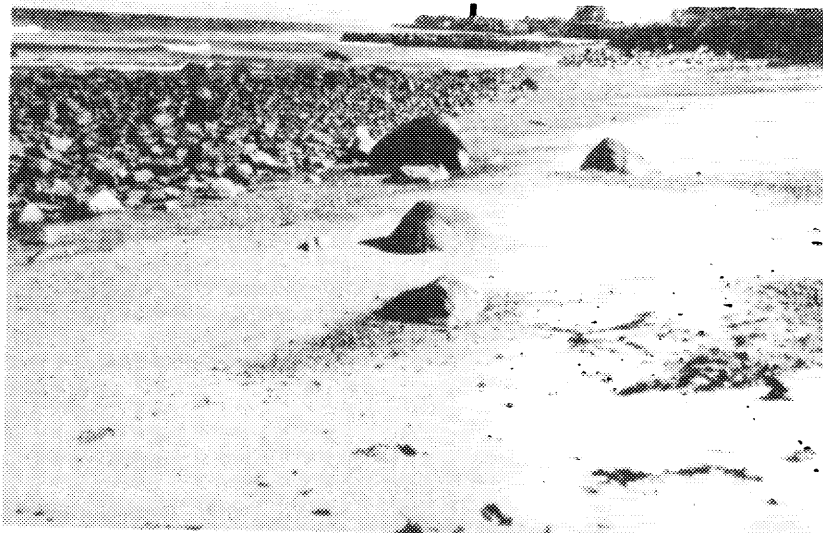


FIG.13. BRANT ROCK, MARSHFIELD. September 18, 1956. South from about center of beach.



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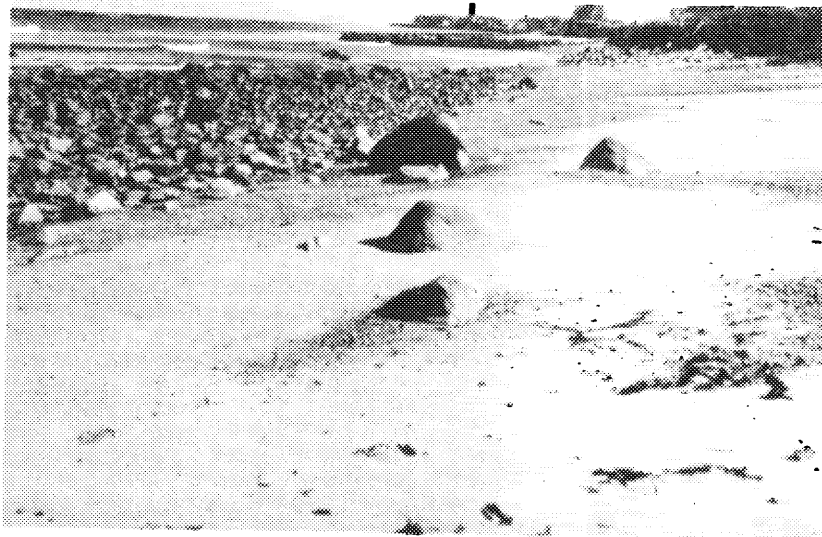


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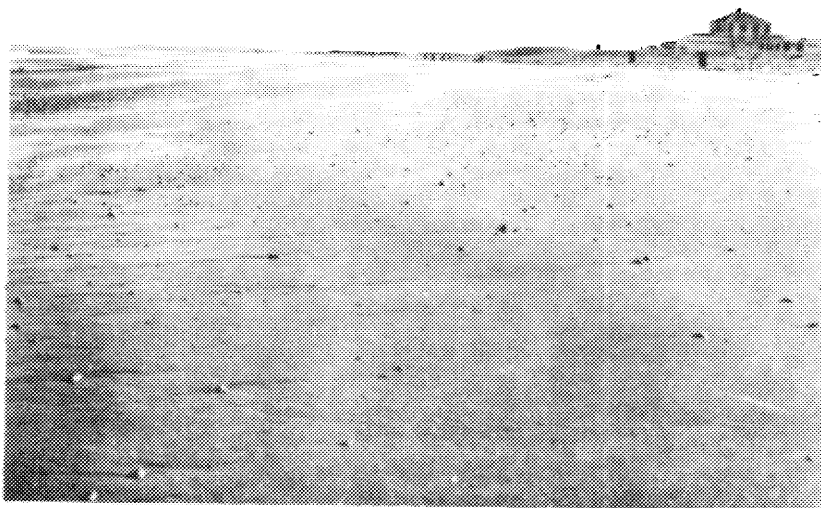


FIG.15. DUXBURY BEACH, DUXBURY. September 18, 1956. South from a point north of Duxbury Beach bathhouse.



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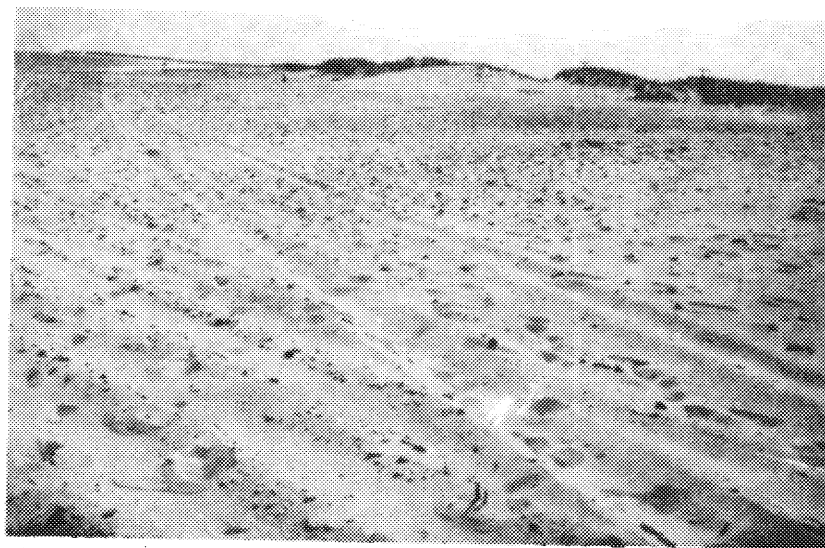


FIG.16. DUXBURY BEACH, DUXBURY. September 19, 1956. South along Duxbury Beach tombolo from vicinity Powder Point bridge.



FIG.17. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit from a point about 1/2 mile from base.



FIG.18. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit at outer end.

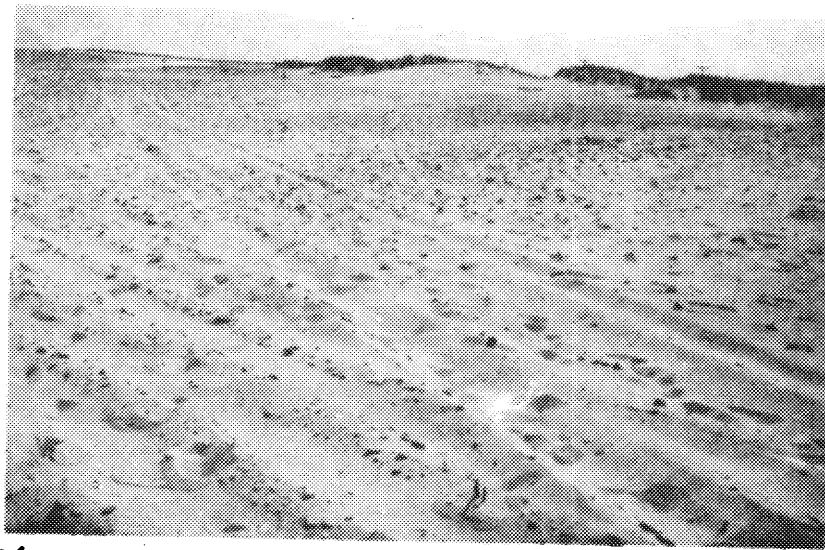


FIG.16. DUXBURY BEACH, DUXBURY. September 19, 1956. South along Duxbury Beach tombolo from vicinity Powder Point bridge.



FIG.17. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit from a point about 1/2 mile from base.



FIG.18. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit at outer end.

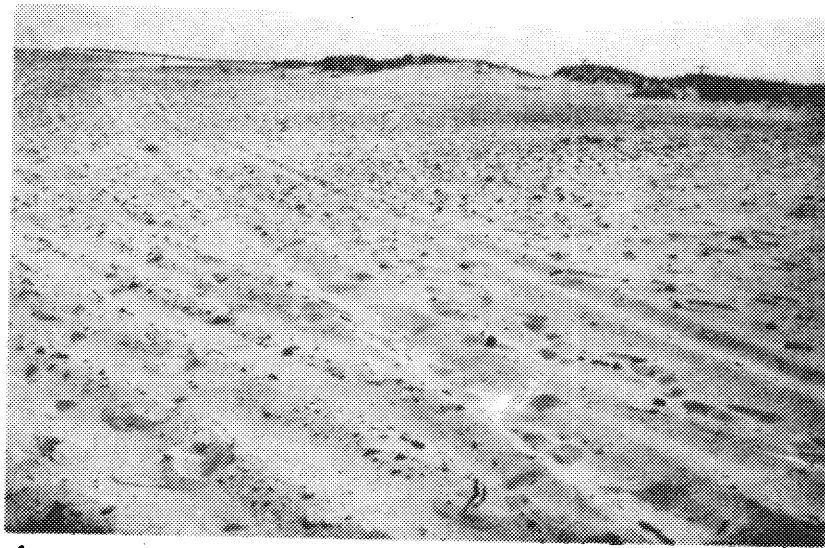


FIG.16. DUXBURY BEACH, DUXBURY. September 19, 1956. South along Duxbury Beach tombolo from vicinity Powder Point bridge.



FIG.17. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit from a point about 1/2 mile from base.



FIG.18. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit at outer end.

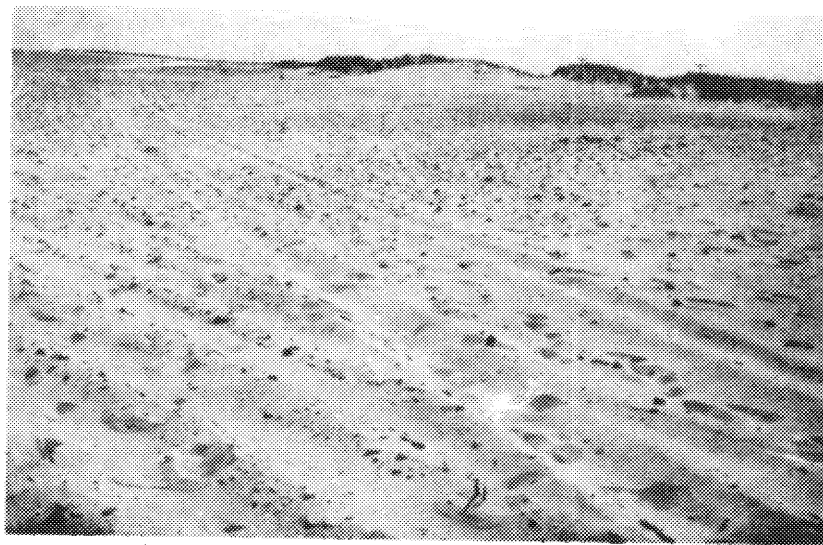


FIG.16. DUXBURY BEACH, DUXBURY. September 19, 1956. South along Duxbury Beach tombolo from vicinity Powder Point bridge.



FIG.17. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit from a point about 1/2 mile from base.



FIG.18. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit at outer end.

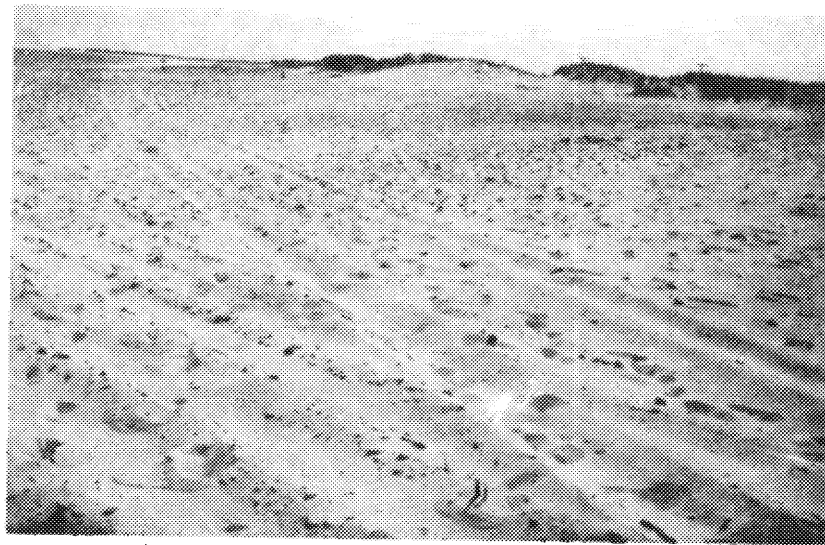


FIG.16. DUXBURY BEACH, DUXBURY. September 19, 1956. South along Duxbury Beach tombolo from vicinity Powder Point bridge.



FIG.17. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit from a point about 1/2 mile from base.



FIG.18. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit at outer end.

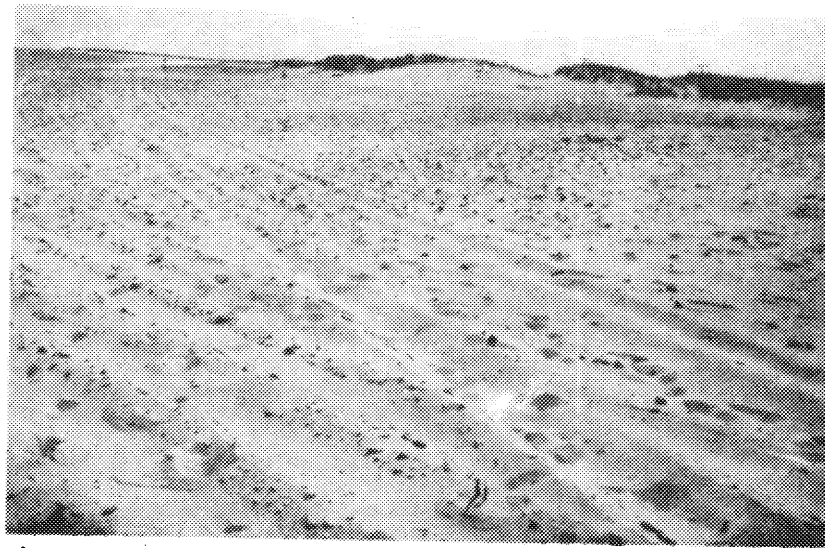


FIG.16. DUXBURY BEACH, DUXBURY. September 19, 1956. South along Duxbury Beach tombolo from vicinity Powder Point bridge.



FIG.17. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit from a point about 1/2 mile from base.



FIG.18. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit at outer end.

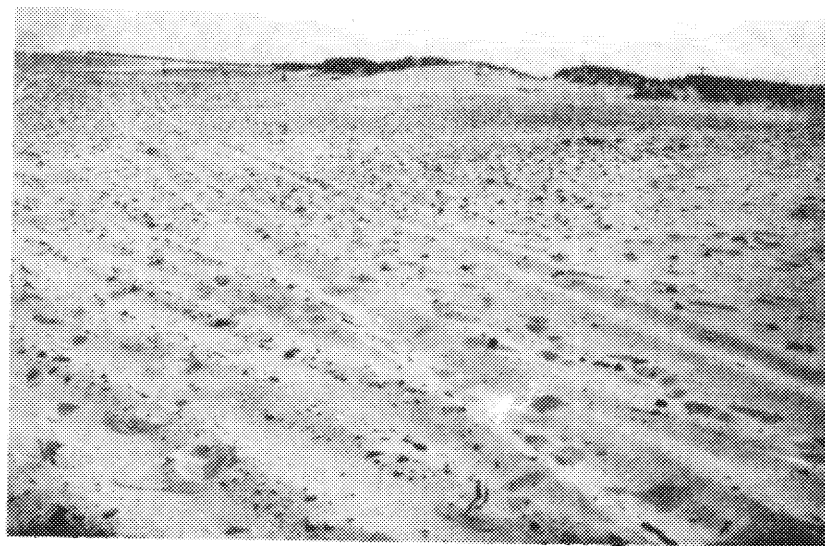


FIG.16. DUXBURY BEACH, DUXBURY. September 19, 1956. South along Duxbury Beach tombolo from vicinity Powder Point bridge.



FIG.17. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit from a point about 1/2 mile from base.



FIG.18. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit at outer end.

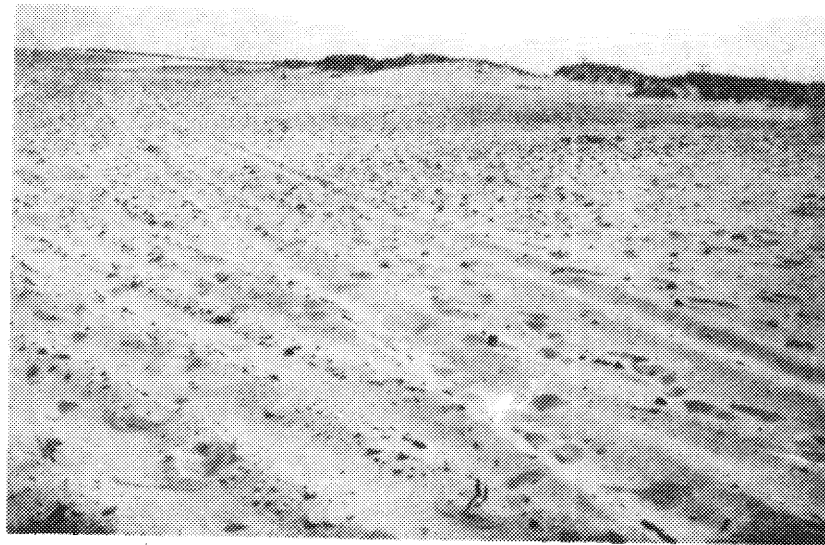


FIG.16. DUXBURY BEACH, DUXBURY. September 19, 1956. South along Duxbury Beach tombolo from vicinity Powder Point bridge.



FIG.17. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit from a point about 1/2 mile from base.



FIG.18. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit at outer end.

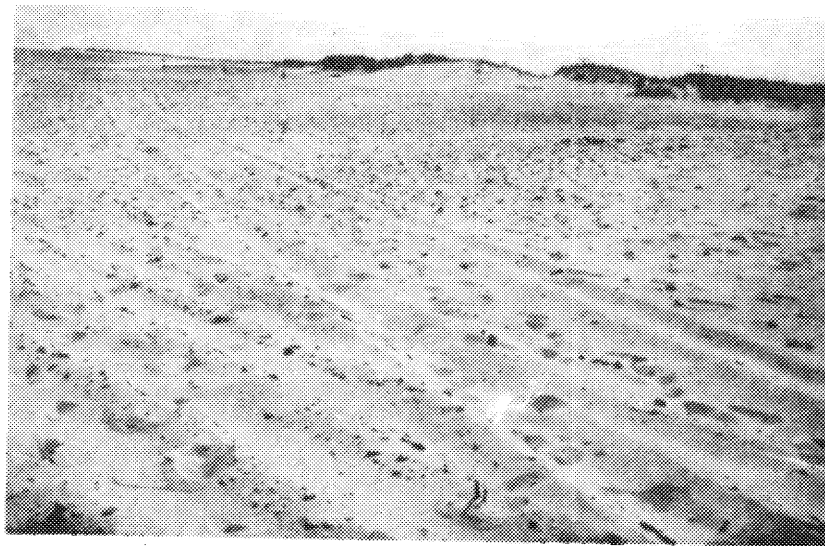


FIG.16. DUXBURY BEACH, DUXBURY. September 19, 1956. South along Duxbury Beach tombolo from vicinity Powder Point bridge.



FIG.17. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit from a point about 1/2 mile from base.



FIG.18. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit at outer end.

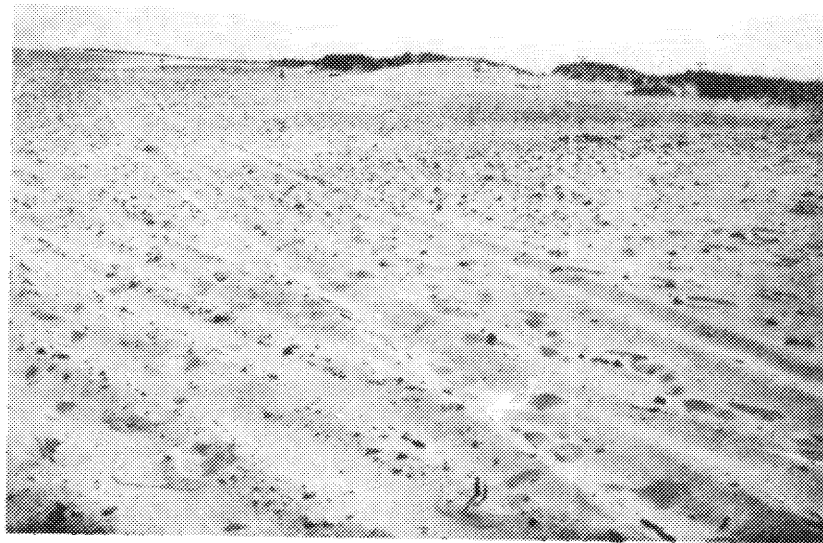


FIG.16. DUXBURY BEACH, DUXBURY. September 19, 1956. South along Duxbury Beach tombolo from vicinity Powder Point bridge.



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FIG.18. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit at outer end.

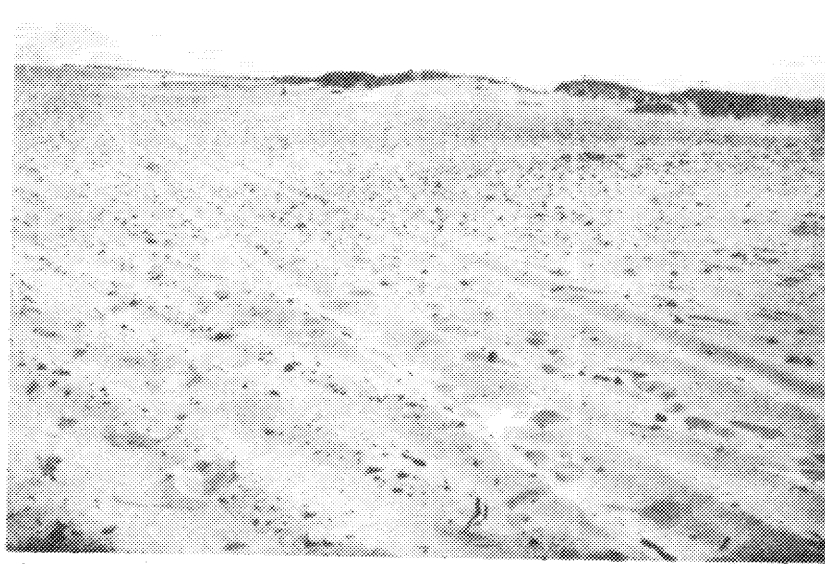


FIG.16. DUXBURY BEACH, DUXBURY. September 19, 1956. South along Duxbury Beach tombolo from vicinity Powder Point bridge.



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FIG.18. PLYMOUTH (LONG) BEACH, PLYMOUTH. April 16, 1957. Northeast along spit at outer end.

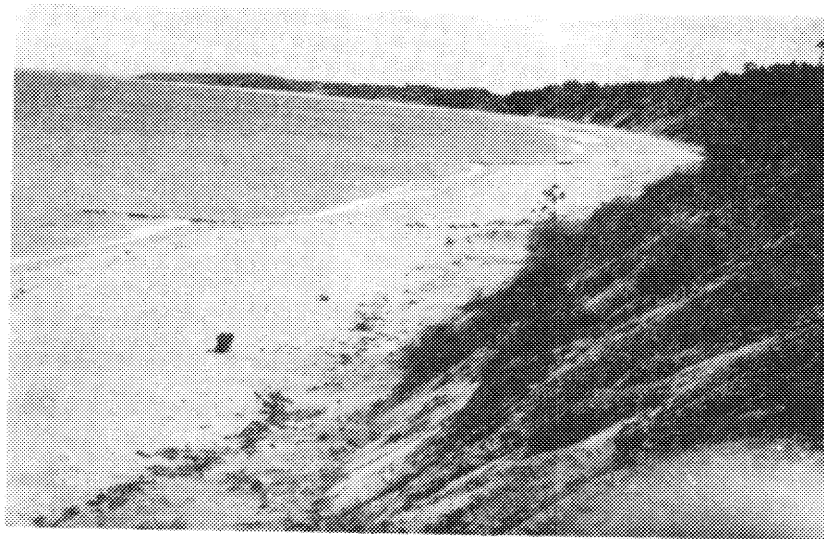


FIG.22. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. South along the groin system in vicinity of Fishermans Landing.

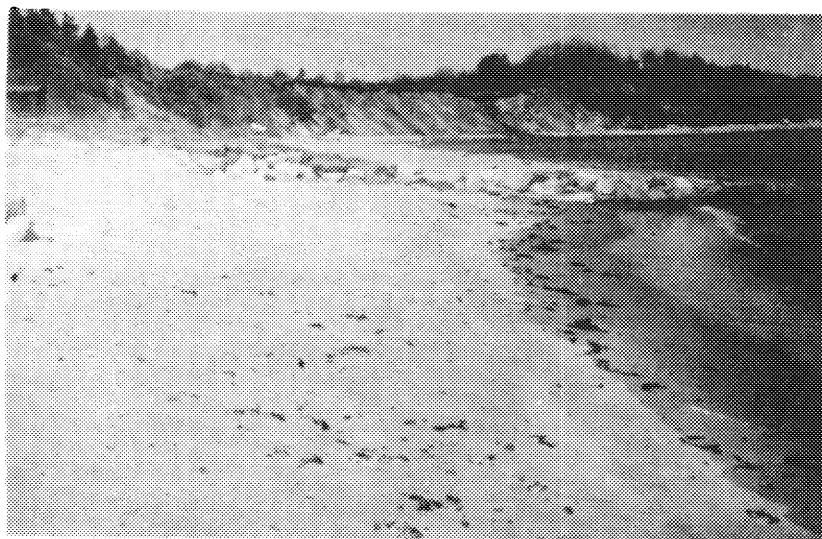


FIG.23. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. North toward Stage Point.



FIG.24. INDIAN HILL, PLYMOUTH. April 4, 1957. South along face of Indian Hill.

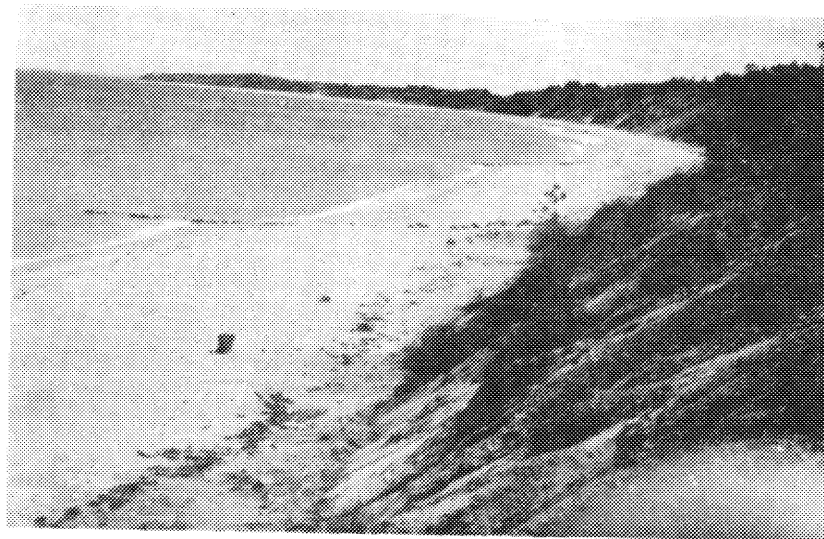


FIG.22. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. South along the groin system in vicinity of Fishermans Landing.



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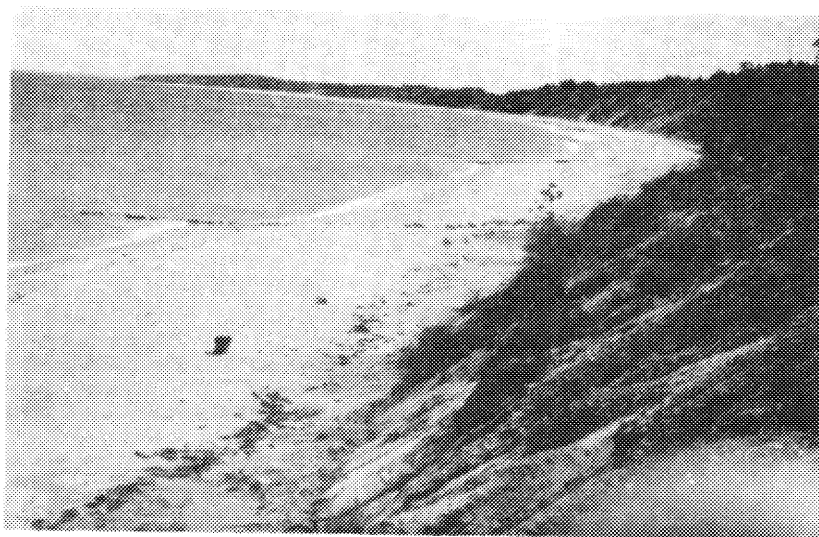


FIG.22. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. South along the groin system in vicinity of Fishermans Landing.



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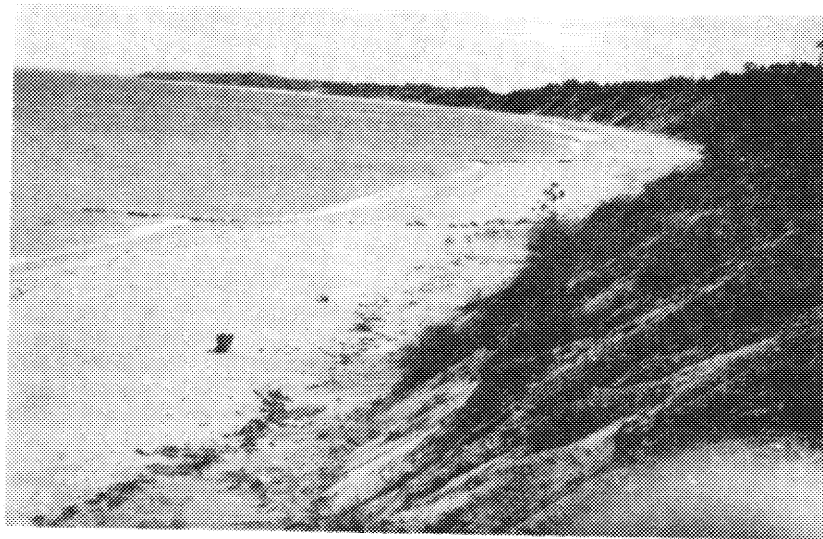


FIG.22. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. South along the groin system in vicinity of Fishermans Landing.

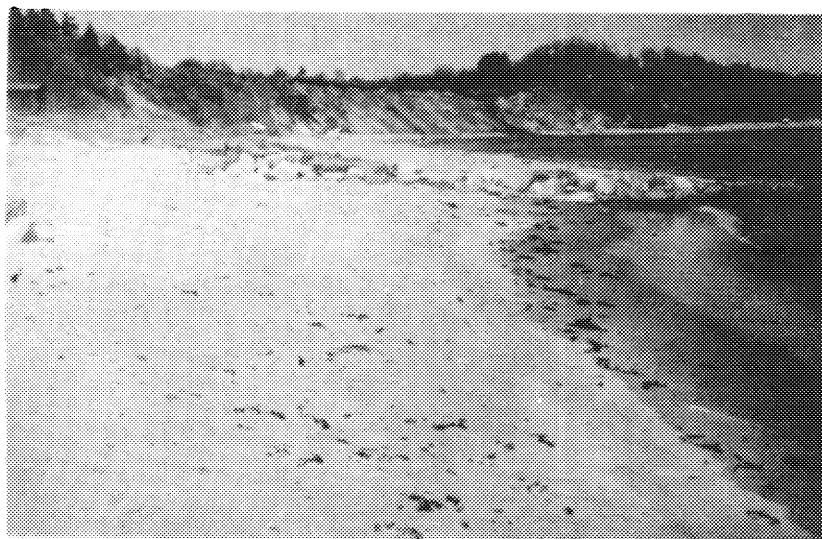


FIG.23. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. North toward Stage Point.



FIG.24. INDIAN HILL, PLYMOUTH. April 4, 1957. South along face of Indian Hill.

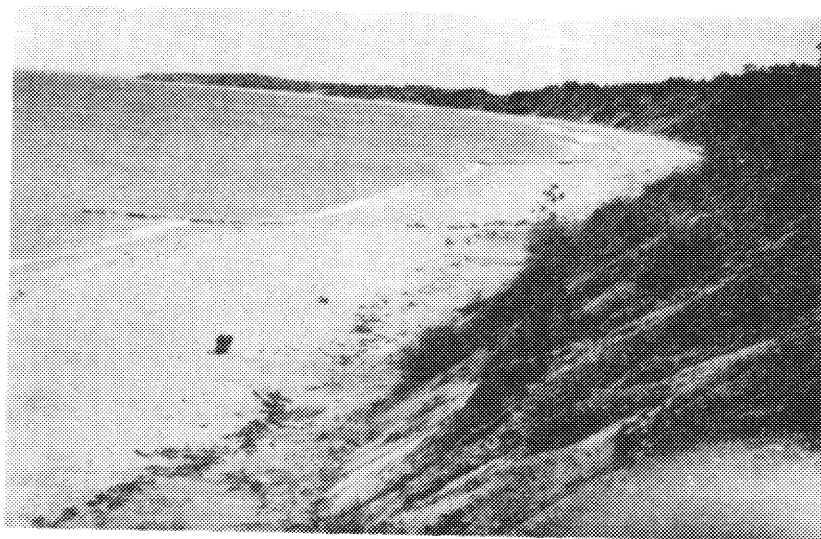


FIG.22. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. South along the groin system in vicinity of Fishermans Landing.

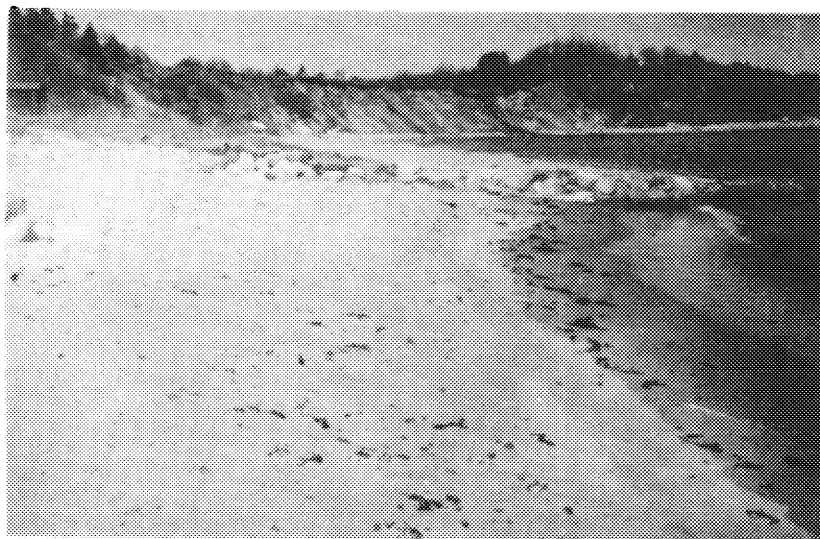


FIG.23. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. North toward Stage Point.



FIG.24. INDIAN HILL, PLYMOUTH. April 4, 1957. South along face of Indian Hill.

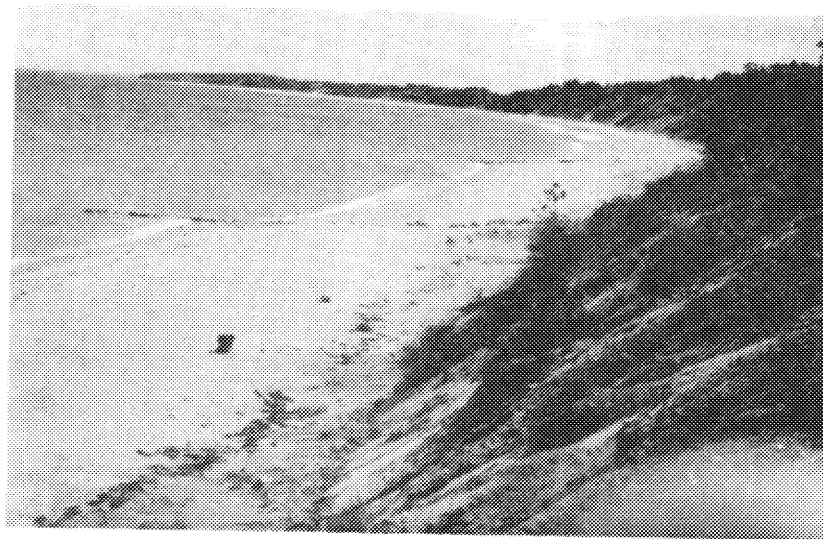


FIG.22. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. South along the groin system in vicinity of Fishermans Landing.

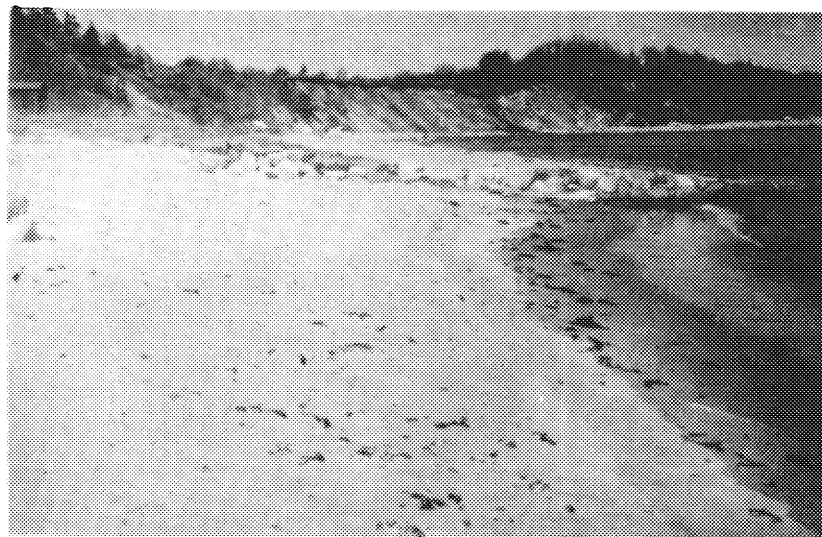


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FIG.24. INDIAN HILL, PLYMOUTH. April 4, 1957. South along face of Indian Hill.

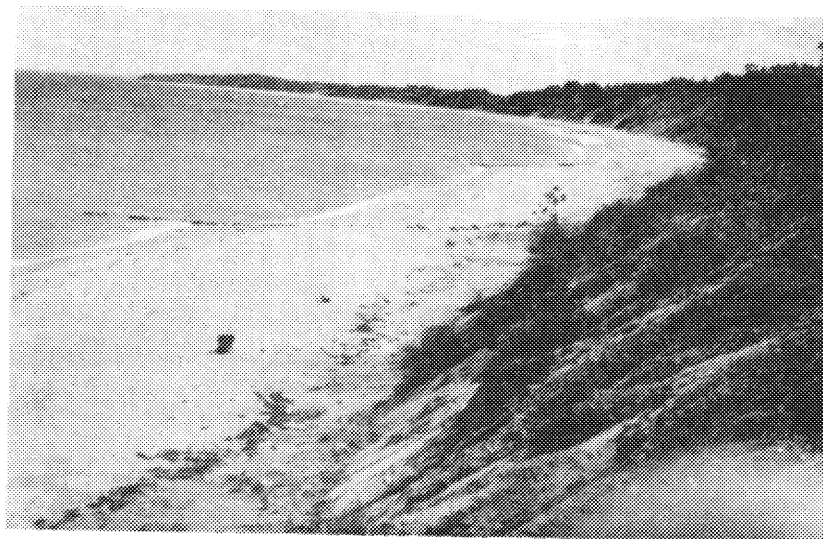


FIG.22. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. South along the groin system in vicinity of Fishermans Landing.



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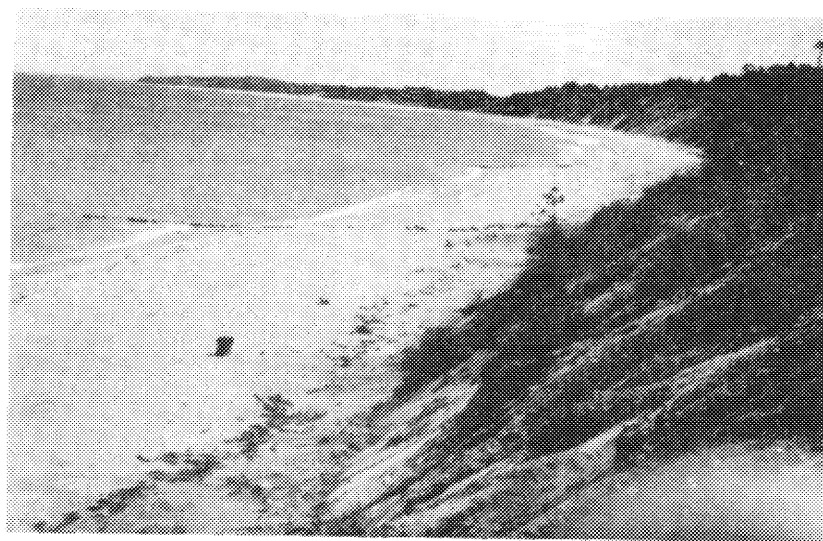


FIG.22. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. South along the groin system in vicinity of Fishermans Landing.



FIG.23. MANOMET BLUFFS, PLYMOUTH. April 4, 1957. North toward Stage Point.



FIG.24. INDIAN HILL, PLYMOUTH. April 4, 1957. South along face of Indian Hill.



FIG.25. VALLERSVILLE, PLYMOUTH. April 4, 1957.
South along beach.

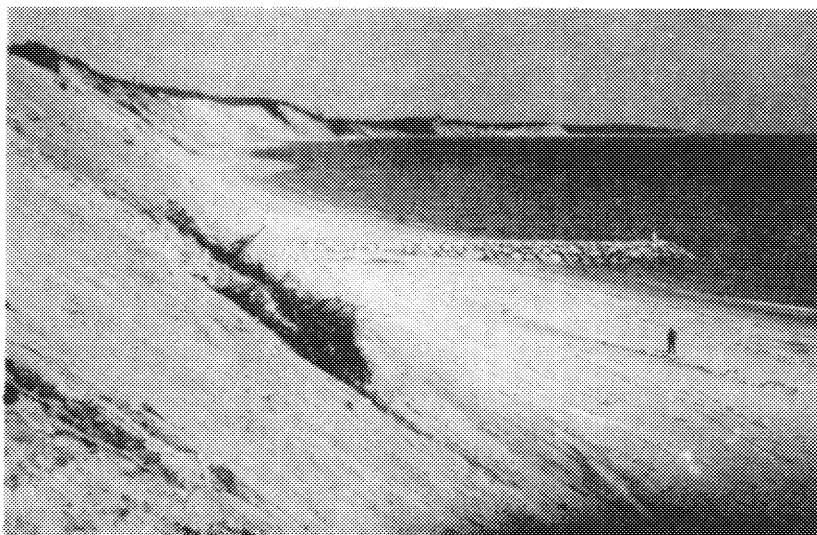


FIG.26. NAMMOC HEIGHTS, PLYMOUTH. April 24, 1957.
North from a point just north of Peaked Cliff.

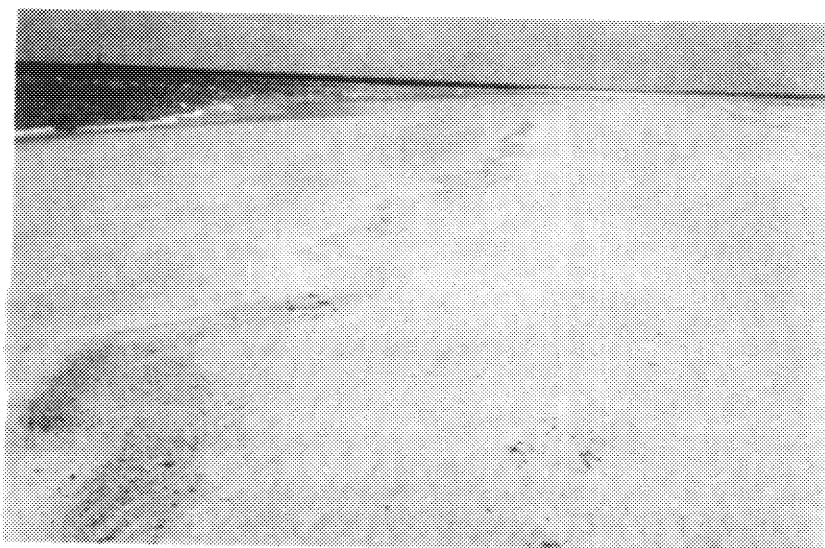


FIG.27. SCUSSET BEACH, SANDWICH. April 24, 1957.
South toward north breakwater of Cape Cod Canal.

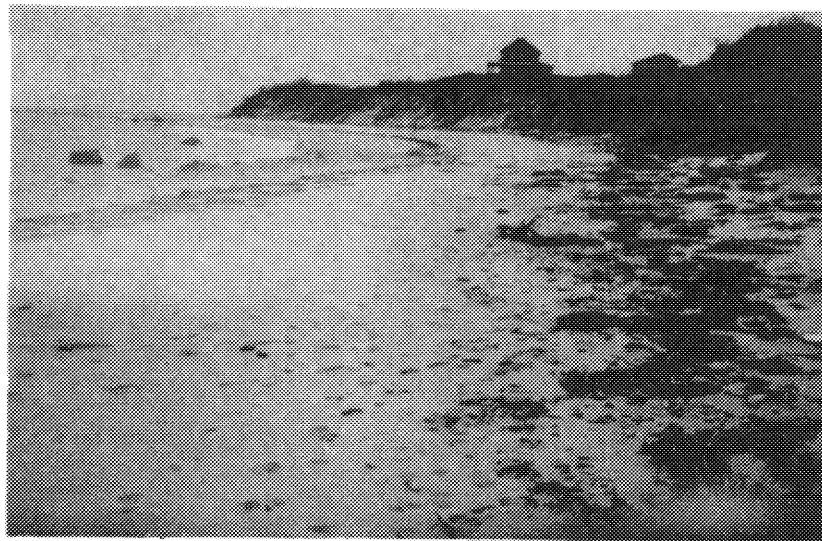


FIG.25. VALLERSVILLE, PLYMOUTH. April 4, 1957.
South along beach.

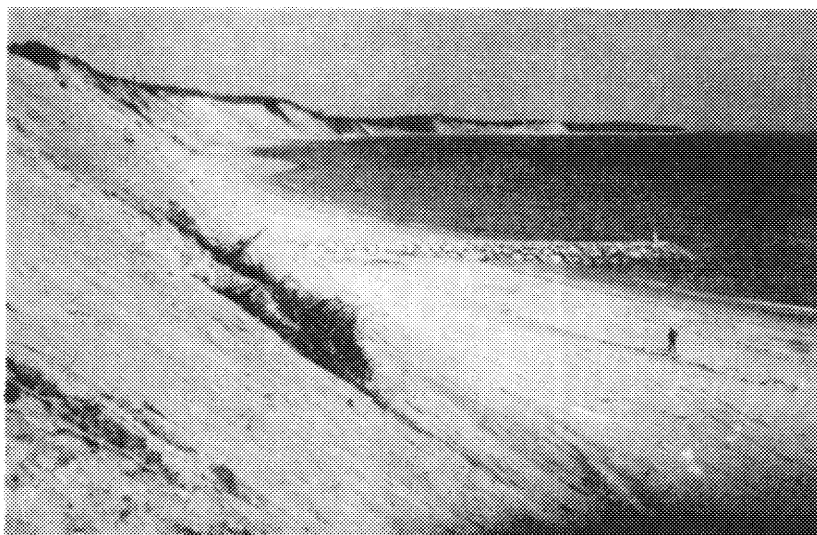


FIG.26. NAMESLOG HEIGHTS, PLYMOUTH. April 24, 1957.
North from a point just north of Peaked Cliff.

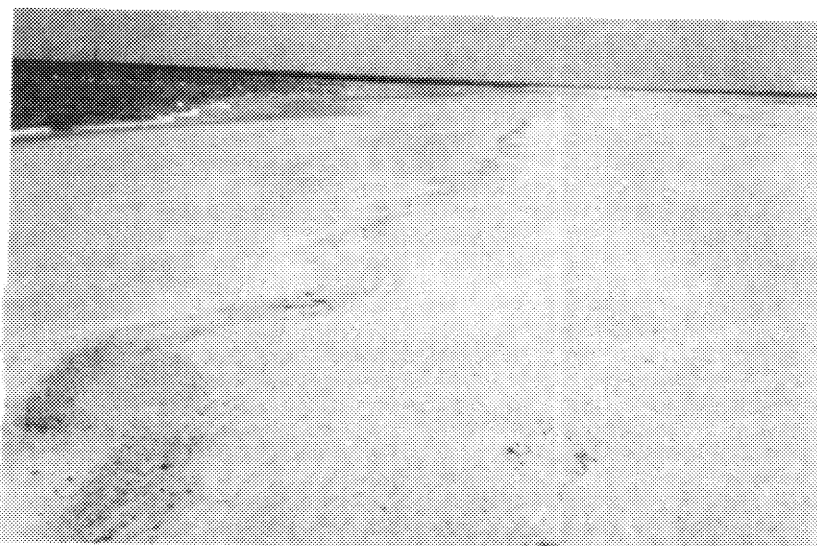


FIG.27. SCUSSET BEACH, SANDWICH. April 24, 1957.
South toward north breakwater of Cape Cod Canal.



FIG.25. VALLERSVILLE, PLYMOUTH. April 4, 1957.
South along beach.

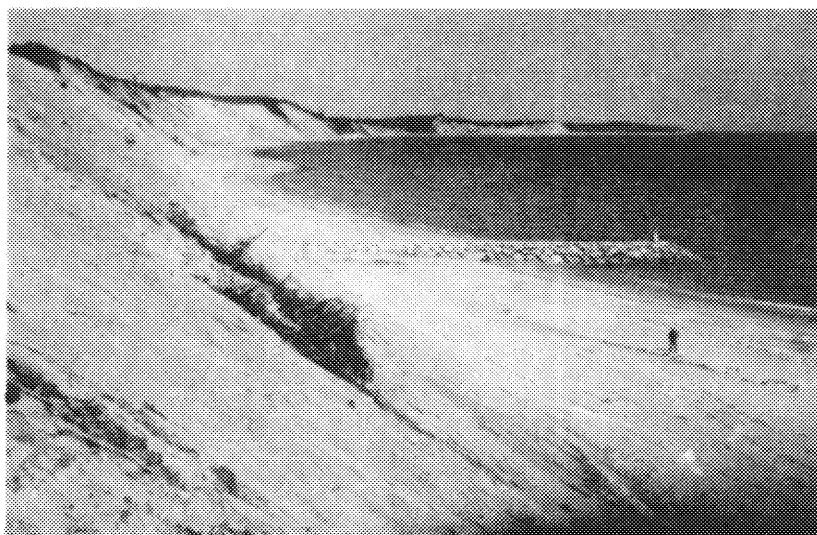


FIG.26. NAMETLOC HEIGHTS, PLYMOUTH. April 24, 1957.
North from a point just north of Peaked Cliff.

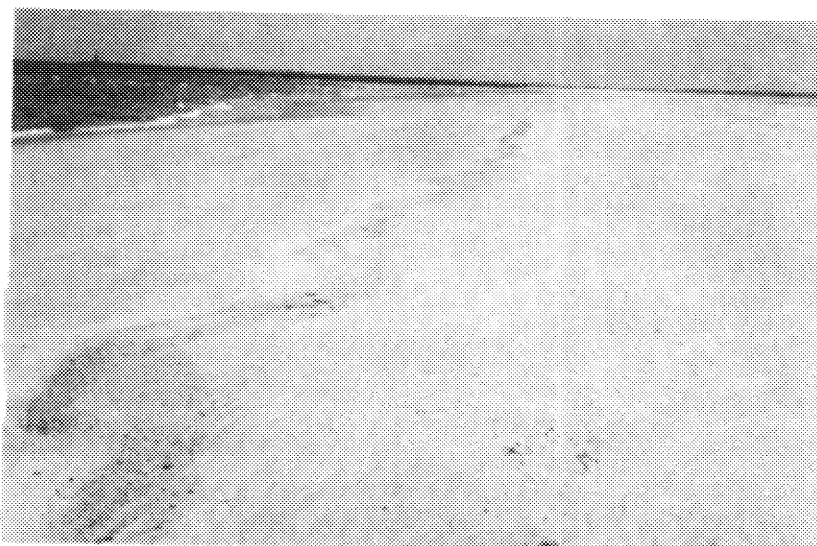


FIG.27. SCUSSET BEACH, SANDWICH. April 24, 1957.
South toward north breakwater of Cape Cod Canal.



FIG.25. VALLERSVILLE, PLYMOUTH. April 4, 1957.
South along beach.

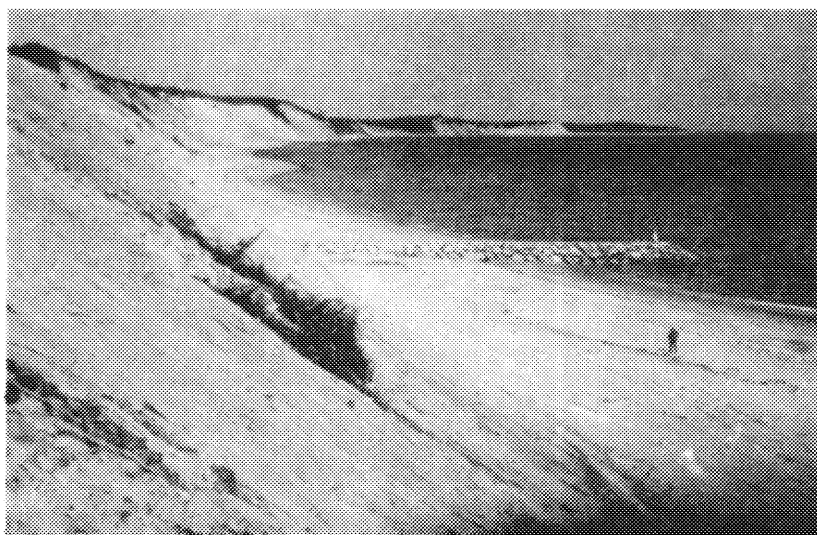


FIG.26. NAMESLOC HEIGHTS, PLYMOUTH. April 24, 1957.
North from a point just north of Peaked Cliff.

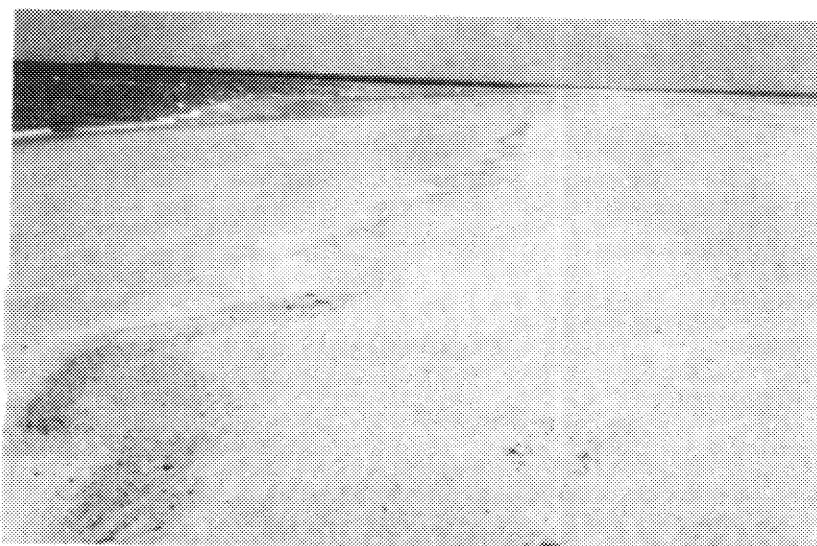


FIG.27. SCUSSET BEACH, SANDWICH. April 24, 1957.
South toward north breakwater of Cape Cod Canal.



FIG.25. VALLERSVILLE, PLYMOUTH. April 4, 1957.
South along beach.

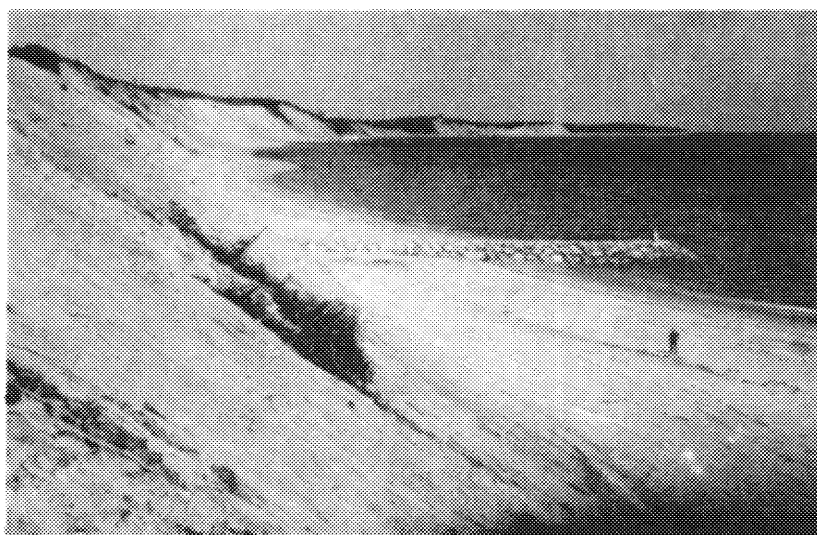


FIG.26. NAMESLOC HEIGHTS, PLYMOUTH. April 24, 1957.
North from a point just north of Peaked Cliff.

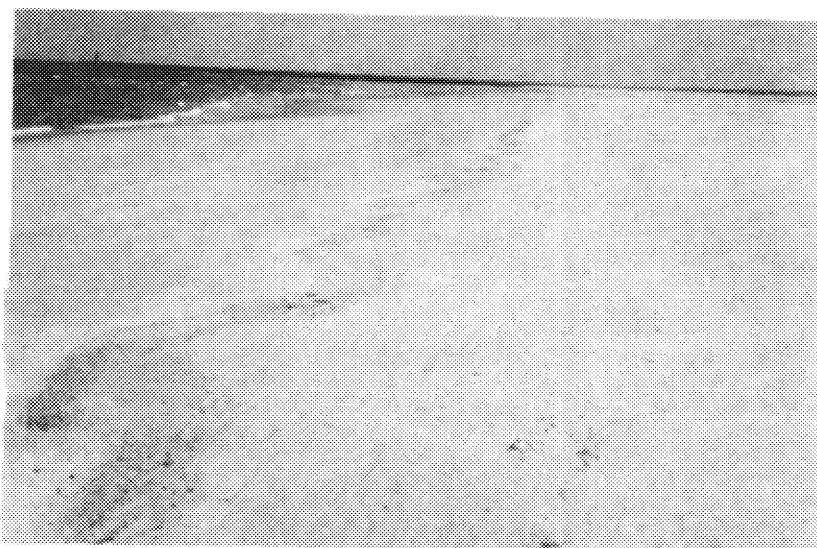


FIG.27. SCUSSET BEACH, SANDWICH. April 24, 1957.
South toward north breakwater of Cape Cod Canal.



FIG.25. VALLERSVILLE, PLYMOUTH. April 4, 1957.
South along beach.

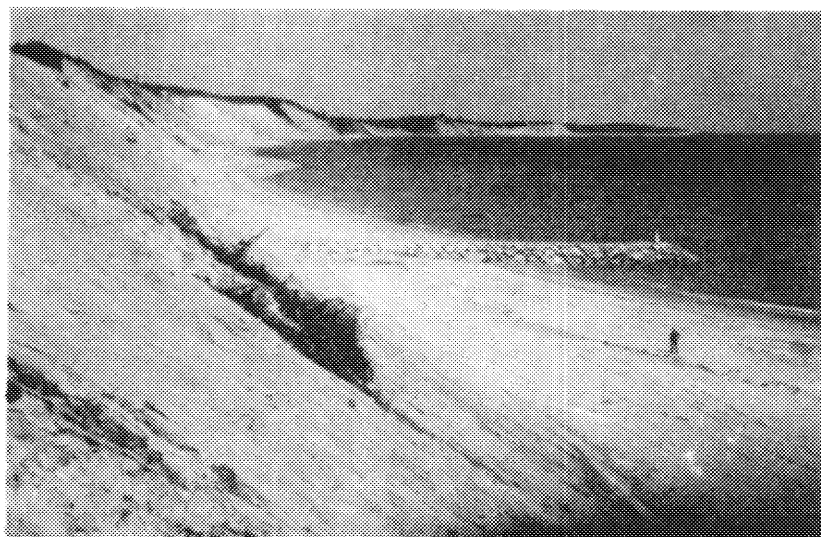


FIG.26. NAMELOC HEIGHTS, PLYMOUTH. April 24, 1957.
North from a point just north of Peaked Cliff.

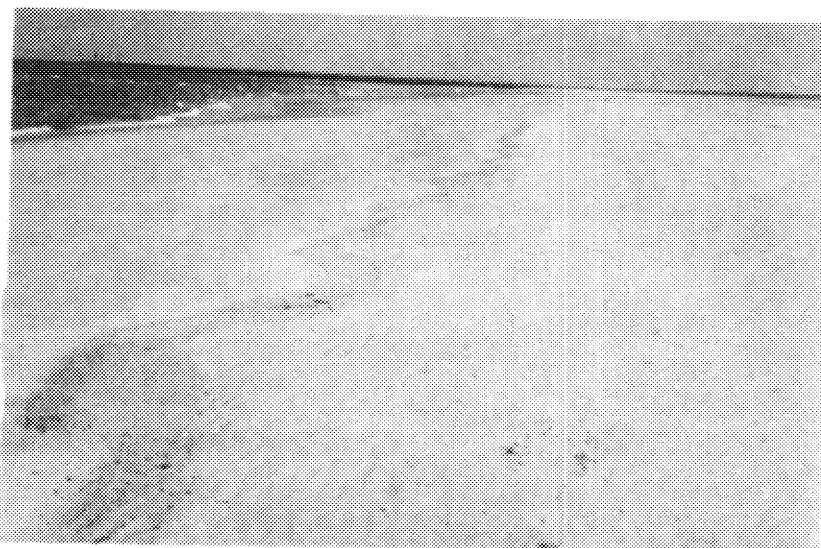


FIG.27. SCUSSET BEACH, SANDWICH. April 24, 1957.
South toward north breakwater of Cape Cod Canal.



FIG.25. VALLERSVILLE, PLYMOUTH. April 4, 1957.
South along beach.

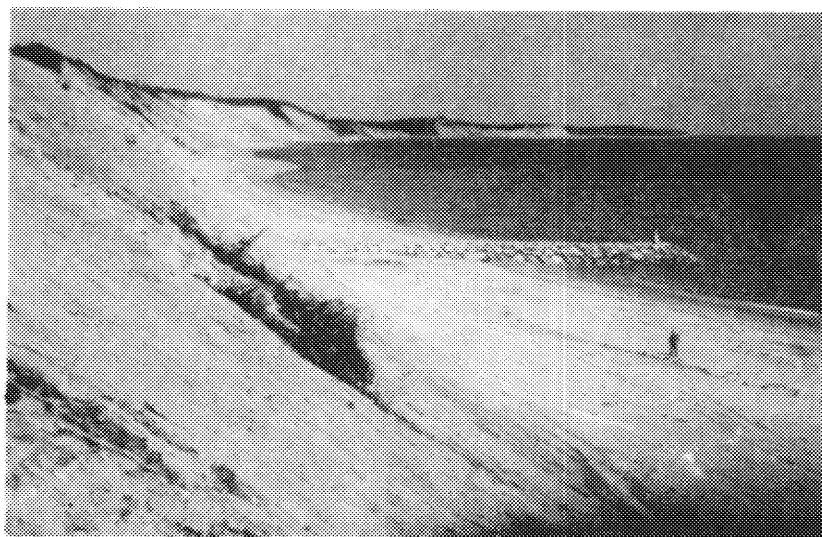


FIG.26. NAMELOC HEIGHTS, PLYMOUTH. April 24, 1957.
North from a point just north of Peaked Cliff.

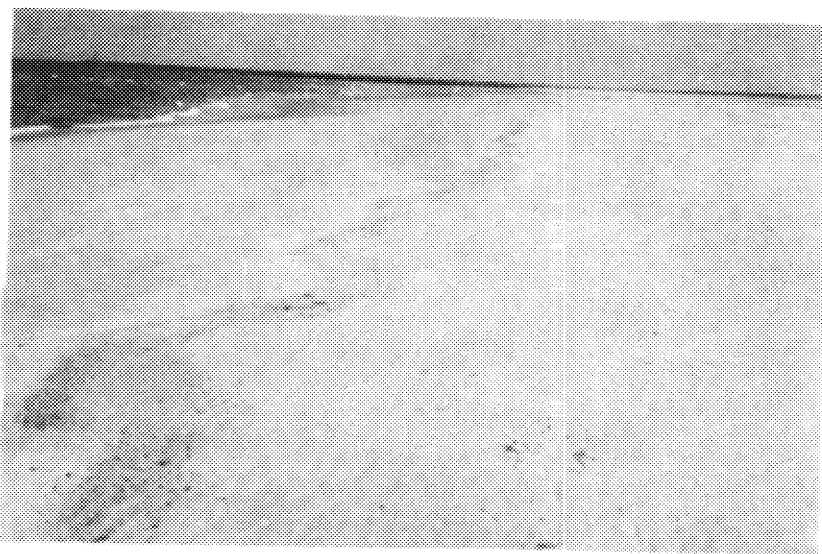


FIG.27. SCUSSET BEACH, SANDWICH. April 24, 1957.
South toward north breakwater of Cape Cod Canal.



FIG.25. VALLERSVILLE, PLYMOUTH. April 4, 1957.
South along beach.

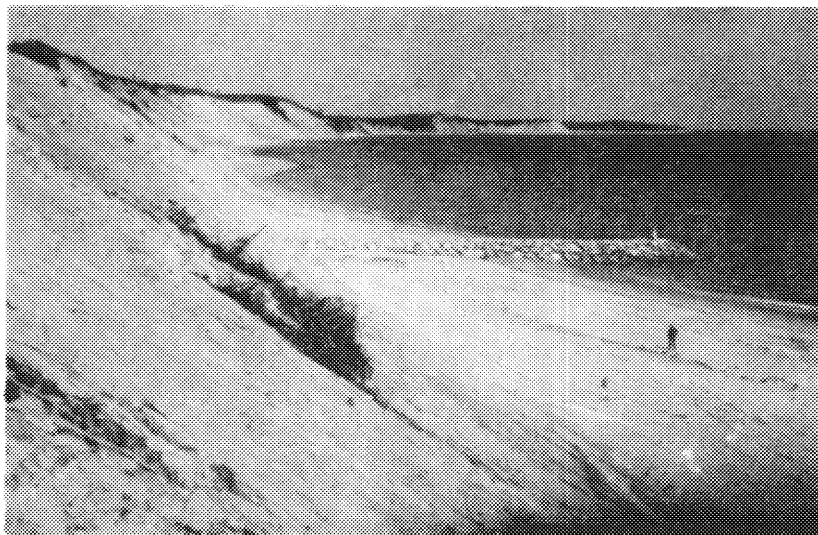


FIG.26. NAMETOC HEIGHTS, PLYMOUTH. April 24, 1957.
North from a point just north of Peaked Cliff.

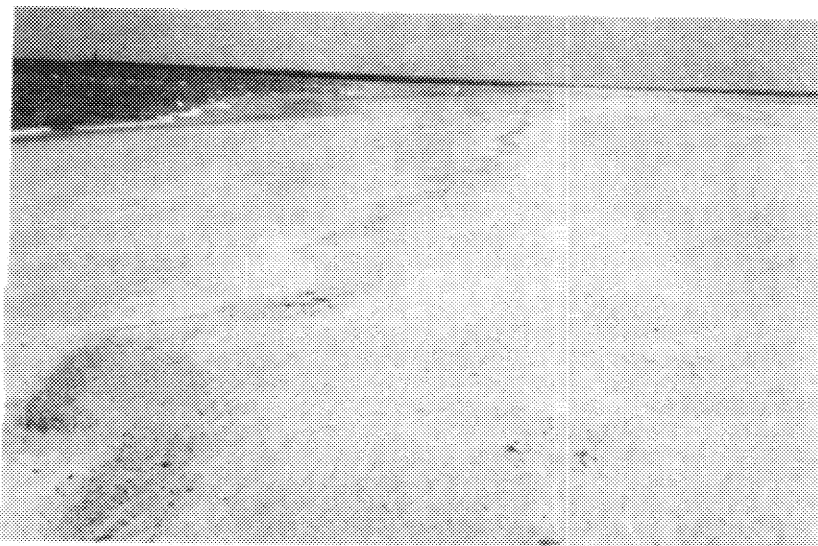


FIG.27. SCUSSET BEACH, SANDWICH. April 24, 1957.
South toward north breakwater of Cape Cod Canal.



FIG.25. VALLERSVILLE, PLYMOUTH. April 4, 1957.
South along beach.

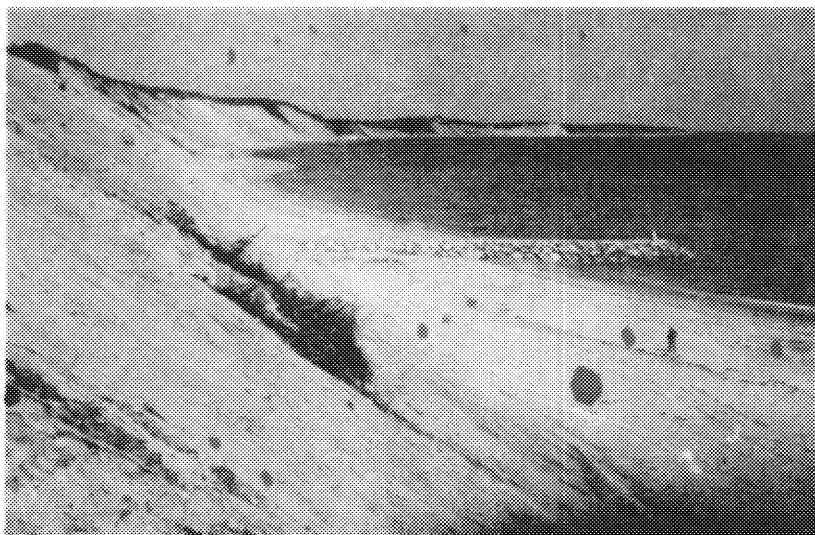


FIG.26. NAMALOG HEIGHTS, PLYMOUTH. April 24, 1957.
North from a point just north of Peaked Cliff.

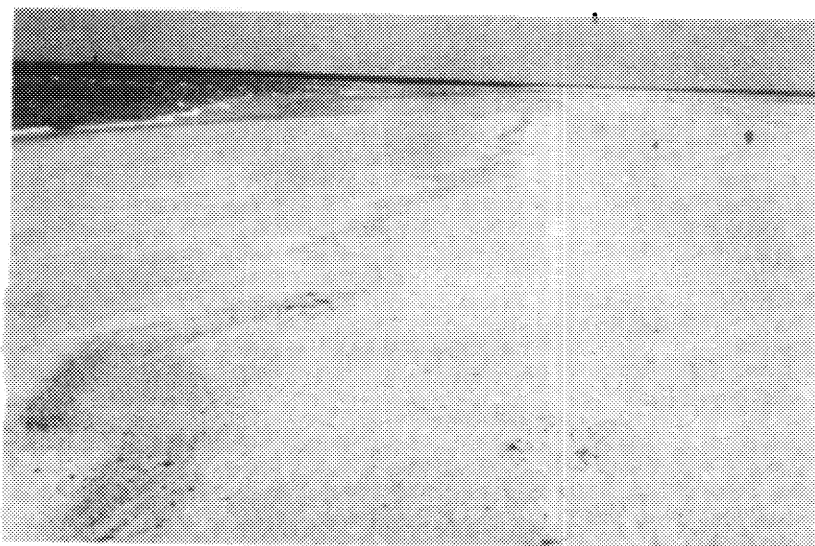


FIG.27. SCUSSET BEACH, SANDWICH. April 24, 1957.
South toward north breakwater of Cape Cod Canal.